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VOLUNTARY SELF-CONTROL OF SLEEP

TO FACILITATE QUASI-CONTINUOUS PERFORMANCE

David F. Dinges, Martin T. Orne, Emily Carota Orne, and Frederick J. Evans

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① VOLUNTARY SELF-CONTROL OF SLEEP
TO FACILITATE QUASI-CONTINUOUS PERFORMANCE,

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David F. Dinges, Martin T. Orne, Emily Carota Orne, and Frederick J. Evans

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Contributors to the Pennsylvania Hospital
Philadelphia, Pennsylvania 19107
Martin T. Orne, M.D., Ph.D.
Principal Investigator

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ABSTRACT

Quasi-continuous work schedules require individuals to function for prolonged periods with few extensive sleep opportunities. Consequently, sleep loss may jeopardize effective functioning. The aim of our research has been to evaluate the potential of napping to facilitate functioning in such situations. Our studies have focused on identifying basic individual differences in napping behavior, and determining the implications of these differences for the ability to nap, the nature of naps, the purpose served by naps, and the consequences of napping in both sleep-conducive and non-conducive (alerting) environments. These issues are highly relevant to the implementation of prophylactic napping during sustained operations. We present an extensive study involving both laboratory and field data on the sleep/wakefulness patterns, napping behavior, psychophysiology, performance, subjective activation, and circadian variation in two types of habitual nappers and a group of habitual non-nappers. Replacement nappers nap to compensate for shortened nocturnal sleep the night before, and are the most common type of nappers; appetitive nappers' naps are not tied to reduced nocturnal sleep, but rather may be part of a natural biphasic sleep cycle. Appetitive nappers exhibit a greater control over napping than replacement nappers. Confirmed non-nappers avoid napping because it produces unpleasant consequences for them, the basis of which might be the intrusion of a consolidated nocturnal sleep pattern into their nap. Naps profoundly improve positive mood states in nappers, but they also yield immediate post-nap performance decrements -- related to aspects of sleep infrastructure -- that are relatively quickly dissipated. Alerting environments and intense waking stimuli do little to lessen the decrements. An alerting nap environment increases the proportion of light sleep during a nap while reciprocally decreasing deep sleep, but only marginally diminishes the subjective benefits of a nap for nappers. Nappers preparing to nap show lowered activation levels. This may reflect an increased sleepiness due to sleep need, as seen in replacement nappers, or be indicative of control over daytime sleep, as seen in appetitive nappers. This preparatory response -- which appears to predict whether sleep will occur -- has implications for training soldiers to use available slack times for napping during quasi-continuous operations. Our findings are reviewed in the context of relevant literature on napping and fragmented sleep, and interpreted in terms of contemporary theories of sleep function. We propose that the next study involve a specific test of the efficacy of prophylactic napping to minimize the accumulation of sleep debt and its accompanying performance deficit. Finally, future investigations should focus on factors that may enhance the control of sleep onset (without sleep debt), and the attenuation of the negative effects of sleep offset.

Descriptors:

Sleep	EEG	Prophylactic Napping
Napping	Circadian Rhythms	Environmental Effects
Fatigue	Activation	Psychophysiology
Performance	Mood	Replacement Nappers
Sustained Operations	Control of Sleep	Appetitive Nappers

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FOREWORD

In conducting the research described in this report the investigators adhered to the Institutional Guide to DHEW Policy on Protection of Human Subjects as outlined by the National Institute of Mental Health. The Research Review Committee of The Pennsylvania Hospital evaluates the protocols of studies being conducted, the type of subjects, method of recruitment, screening process, as well as the risks, voluntary participation and the manner in which informed consent is obtained. The procedures were most recently reviewed and approved on May 15, 1979.

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I. BACKGROUND

Sleep is so fundamentally a part of our daily lives, and its absence during a 24-hour period makes us so subjectively uncomfortable, that there are few of us who do not intuitively consider sleep to be a need as basic to survival as food. Indeed, we average a third of our lives fulfilling a recurrent urge to sleep presumably to recover from the day's fatigue. Most of us would quickly confirm that simply resting each day, without actually sleeping, neither provides the sense of satisfaction we typically feel after a normal night's sleep nor forestalls the growing pressure to sleep after even short periods of sleep deprivation (Kleitman, 1963; Webb & Agnew, 1974a; Lubin, Hord, Tracey, & Johnson, 1976).

Despite the ubiquitous nature of sleep, and the apparently obvious relationship between sleep and recovery from fatigue, the precise physiological benefits that result from sleep remain obscure. Although hundreds of total, partial, and selective sleep deprivation experiments carried out in the past 20 years have documented the dynamic psychophysiological nature of sleep, its multiphasic structure, and behavioral and psychological correlates of it, relatively little insight has been gained into the association between sleep and recovery from fatigue.

Nevertheless, sleep loss does disrupt effective functioning of the individual. Studies of performance, psychological stability, and neurological integrity following sleep deprivation in the laboratory have shown debilitating effects after prolonged periods of wakefulness. The effects are not, however, as obvious as one might expect. Whereas

prolonged sleep loss clearly results in increased irritability, lapses of attention, increased sensitivity to pain, and eventually fine hand tremor, diplopia, and drooping eyelids, it does not produce performance decrements on short, well-learned, interesting tasks, nor does it inevitably result in either profound psychopathology or gross neurological impairment (see Johnson & Naitoh, 1974). Further, highly motivated individuals are capable of maintaining relatively good levels of performance for some time, but their functioning on boring, complex tasks requiring continuous attention inevitably shows progressively greater decrements (see Naitoh, 1969; Johnson & Naitoh, 1974). Similarly, in field studies of individuals engaged in quasi-continuous operations, sleep deprivation effects (on all but simple overlearned tasks) are evident relatively early, and can become severe enough in three days to render the individual "militarily ineffective" (Haslam, 1981). Just as motivation in the laboratory can sustain functioning for longer periods, camaraderie, leadership, and good environmental conditions in the field can to some degree attenuate the effects of sleep loss. Inevitably, however, positive mood declines, errors increase, and overall effectiveness drops off.

While there appears to be no way to adequately restore effectiveness without permitting individuals to sleep, there is an increasing amount of data indicating that short periods of sleep -- naps -- are disproportionately effective in recovering or sustaining functioning relative to either no sleep at all (Lubin et al., 1976), or a single reduced period of sleep (Hartley, 1974). Naps have the advantage of more readily fitting

within the time demands of quasi-continuous work schedules, and consequently, we have proposed short sleep periods as a way of preventing the effects of sleep loss during sustained operations. However, we have been impressed by the individual differences in not only the ability to nap, but also in the consequences of naps for waking functioning. An initial step toward investigation of napping in advance of sleep loss demands a thorough understanding of the importance of individual sleep/wakfulness patterns in relation to the consequences of napping (Taub, 1977), the volitional control of sleep onset, and the motivation to utilize a napping opportunity.

In this report we begin by providing an introduction to the problem of sleep need and quasi-continuous performance demands, and the role prophylactic napping may play in satisfying both aspects, as well as outlining our research strategy for investigating napping ability and consequences. We then review the relevant literature on napping, normal functioning, and sleep loss, including both extensive laboratory investigations, as well as some very recent, highly relevant field studies involving short sleep periods during continuous operations, and conclude with an overview of the issues our work sought to address.

Our major study of individual differences in napping in an optimal (sleep-conducive) and non-optimal (alerting) environment is then described in detail, including complete descriptions of the physiological, performance, subjective, sleep diary, circadian, and survey data collected during the 30 days each subject participated in the study. Following

this are results concerning: the frequency of napping in young adults; individual differences in napping ability and the consequences of napping; psychophysiological and behavioral aspects of control over nap onset and the nature of naps; the immediate and delayed effects of naps on performance and mood; the effects of sleep-conducive and alerting environments on naps and their consequences; the circadian functions of nappers and non-nappers; and the behavioral precursors of napping.

Most of these areas contain data bearing directly on hypotheses we had proposed to understand the nature of naps and individual differences in sleep/wakefulness patterns. Some earlier findings are replicated and new results are presented which reveal intricate relations between naps and waking function. The findings are discussed in light of the literature concerning relevant theoretical and methodological considerations. We conclude with a three-part discussion on: the implications of our work for theories of sleep function, and problems of quasi-continuous operations; the consequences of napping and nap infrastructure on subsequent functioning; and the relevance of the results on the control of nap sleep onset for the implementation of prophylactic napping.

II. INTRODUCTION

A. Review of the Problem.

1. The Need to Sleep.

The need for sleep is universally acknowledged. With prolonged sleep loss the individual feels subjectively fatigued, finds it extremely difficult to remain awake despite environmental stimulation, and eventually shows significant deterioration in performance. Even one day without sleep can yield unpleasant consequences for most of us.

Like the need for food, sleep is generally satisfied on a regular daily basis, though different cultures may vary widely in the pattern by which their members satisfy either.* While it may involve experiencing discomfort and even hardship, it is possible to postpone the need for food or sleep for some period of time. However, when this is done the need eventually becomes prepotent and the individual will show an increased tendency to satisfy it. If circumstances exist that continue to make it impossible to do so, profound behavioral as well as motivational changes typically result (e.g., Haslam, 1981).

*As Rechtschaffen (1979) has pointed out, it is reasonable to conceptualize the need for sleep as analogous to the need for food. The consummatory nature of sleep is suggested by: "the ubiquitousness of sleep across species and within individuals; the periodic occurrence of sleep; the effects of sleep deprivation; the reversal of deficits after recovery of sleep; the correlations between sleep and fundamental biological parameters" (p. 3). Of course, the analogy between food and sleep is strictly conceptual. In no way do we mean to imply that the neurophysiological substrate of sleep is functionally similar to food intake systems. Other investigators, especially Dement (1972), Webb (1975), and Johnson, Naitoh, Moses, and Lubin (1977) have also alluded to such an analogy.

The ability to function in the absence of sleep appears more readily impaired -- particularly in regard to cognitive functions -- than is the case in the absence of food, but the parallel seems unmistakable. However, a major difference does exist. While the basic functions of food consumption and mechanisms of digestion have been increasingly understood, the fundamental questions concerning the functions of sleep have remained unanswered.

Though the past 20 years have seen a remarkable proliferation of sleep research -- with much being learned about its neurophysiology, the relationship of dreams to sleep stages, patterns of sleep in a wide variety of circumstances and how they are affected by illness, drugs, and environmental changes -- considerable speculation persists concerning the purpose of sleep within the broader framework of adaptiveness (Webb, 1979). Restorative or homeostatic theories of sleep suggest that sleep serves to provide physiological and/or psychological restoration of conditions depleted by wakefulness (e.g., Moruzzi, 1966; Oswald, 1970; Hartmann, 1973); while adaptive or biorhythmic theories of sleep posit that sleep is an innate organized behavior pattern that may serve to keep the organism from engaging in wake behavior at maladaptive times (e.g., Webb, 1971; Snyder, 1972; Meddis, 1975).

Sleep deprivation studies have been a common model for studying the functions of sleep. While numerous sleep deprivation experiments have documented the need for sleep, it remains unclear precisely what physiological benefits, if any, sleep provides for the organism. What-

ever occurs physiologically, however, its absence soon makes itself felt. It is remarkable that a phenomenon as basic as sleep, clearly evident even in primitive organisms, has eluded clarification. Although it is now clear that sleep cannot be accounted for merely in terms of rest (Kleitman, 1963; Webb & Agnew, 1974a; Lubin et al., 1976), the basic biological functions of sleep remain obscure.

2. The Study of Napping.

While as scientists we share an intense interest in the physiological and behavioral functions of sleep, our interest in studying the phenomenon also has a practical motivation. We seek to better understand how sleep can be used most efficiently to facilitate recovery from fatigue and maintain the effective functioning of normal individuals. By assessing the relationships between sleep need, physiology, subjective comfort, and performance, we seek to address problems that we view to be intimately related to questions concerned with the effective functioning of soldiers during sustained operations. It is in this context that we have sought to pursue studies exploring the role of napping in maintaining performance and morale under circumstances that might ordinarily yield deteriorations in both of these parameters as a result of sleep deprivation.

While conceptually the idea of increasing the efficient utilization of sleep is appealing, and some research indicates that the gradual reduction of nocturnal sleep can allow individuals to continue to function effectively for long periods with less and apparently more efficient sleep, it

seems clear that there are definite limitations to such an approach (Webb & Agnew, 1974a; Mullaney, Johnson, Naitoh, Friedmann, & Globus, 1977). It appears that it takes months for subjects to fully adapt to reductions of only one to two hours in nocturnal sleep duration. Thus, while the amount of sleep necessary for long term effective functioning can be reduced to a certain degree, the amount of reduction possible appears to be quite limited. From the perspective of quasi-continuous performance where relatively acute changes in sleep/wakefulness cycles are demanded, this type of sleep discipline is likely to have little utility. Further, it does not address the question of the amount of sleep needed to function effectively and more or less continuously for a matter of days or weeks.

The approach to maintaining effective quasi-continuous performance that appears to be most promising to us involves the systematic use of napping. From this perspective, the question emerges whether it is necessary to obtain sleep in one continuous period, or whether segmenting sleep time can serve to satisfy sleep need. Certainly there are many anecdotal reports of individuals functioning almost continually for days at a time, apparently satisfying their sleep need with short naps: noteworthy examples are Napoleon, Thomas Edison, and Winston Churchill. Similarly, a study by Hartley (1974) has shown that subjects are able to function reasonably effectively for four consecutive days with three 80-minute naps per 24 hours (versus one 4-hour sleep period per 24 hours). This finding lent support to our view that the effects of

sleep deprivation could be ameliorated by permitting individuals to have short naps.

3. The Concept of Prophylactic Napping in Relation to Quasi-Continuous Performance.

We began our investigation into the potential of napping during quasi-continuous performance demands by assessing the frequency and nature of naps in the young adult population (Evans & Orne, 1975; Evans, Cook, Cohen, Orne, & Orne, 1976). These early studies revealed that the majority of military age normal young adults who nap, do so in part to make up for an existing nocturnal sleep loss. Such individuals were called replacement nappers, since they napped primarily to compensate or replace lost nocturnal sleep. At times these replacement nappers appeared to anticipate future sleep loss by napping in advance of the forthcoming night's reduced amount of sleep. These individuals appeared to be napping "prophylactically" to avoid the unpleasant effects of sleep deprivation (Evans & Orne, 1975). Such observations contributed to a reconceptualization of how best to approach the problem of continuous performance. Rather than seeking to increase sleep efficiency as such, it seemed most productive to focus instead on developing sleep flexibility.

The possibility of prophylactic napping suggested the need to reconsider how combat personnel might most effectively prevent the chronic effects of sleep deprivation. Traditionally it has been taken for granted that combat personnel are in a chronic state of sleep deprivation, and as a consequence will take advantage of any opportunity for sleep

that is available. Further, it has been assumed that they can disregard physical and psychological circumstances that would normally make the situation uncondusive to sleep. Thus, they may nap despite danger, the likelihood of sudden awakening at an undetermined time (often with immediate demands to function at a high level of proficiency), and the inability to either undress or to find a comfortable resting place. Similarly, neither the presence of noise nor light are sufficient impediments to sleep for the exhausted individual. It is hardly surprising, therefore, that the problem of sleep onset among combat personnel has received scant attention.

As one considers the situation of combat personnel, it is typical that they find themselves in a context which demands high levels of alertness for certain periods of time. Even when the need for a high level of activity and vigilance decreases and the immediate danger has lessened, the state of arousal persists for some time. Accordingly, instead of using the slack period to obtain rest, personnel generally seek to alleviate the fear and anxiety by supportive social interaction. Further, the anticipation of forthcoming combat also serves to maintain arousal during these slack periods, until there is another operational demand for a high level of activity -- though this may be some time in the future. This cycle of high activity and stress alternating with periods of low activity, but high arousal, due to the expectation of impending danger, characterizes sustained combat operations.

These circumstances provide no desirable opportunities for sleep in the sense that the individual remains continuously aroused; there is an implied presence of danger, an absence of quiet, dark, and comfortable private surroundings, and a group ethos against napping, all of which contrive to prevent personnel from sleeping until they have become thoroughly exhausted. Only then are intermittent periods of low demand utilized for sleep. In a sleep-hostile context, sleep opportunities are not usually taken advantage of, largely because most of us have been trained not to sleep unless the circumstances are conducive or extreme fatigue demands it. Consequently, combat personnel take advantage of all opportunities for rest only after they have developed a chronic sleep deficit with all its attendant effects on morale and performance.

On the other hand, if personnel were trained to use any opportunity for short periods of sleep prior to and during combat situations before they have become sleep deprived, the debilitating effects of combat that are mediated by chronic sleep deprivation might be avoided -- allowing personnel to function in the field more effectively over a much longer period of time.

The important point is to prevent, or at least postpone, the development of sleep debt as much as possible. That is, although the loss of a night's sleep can usually be managed by most individuals, the loss of a night's sleep to an individual who is already sleep deprived is likely to result in profound performance decrements. We regard the ability to obtain sleep in non-conducive situations (in the absence of extreme

fatigue) as the basic skill underlying prophylactic napping. While a few individuals practice this skill, we believe that many other individuals can also learn this skill with appropriate training.

4. Systematic Research Needed to Operationalize the Concept of Prophylactic Napping.

In addition to fundamental questions about the ability to store sleep even for short periods, we believe that prophylactic napping has not hitherto been considered for most military applications for several reasons: (1) not all individuals can readily go to sleep if will, and thus, most fail to utilize sleep opportunities until they are exhausted; (2) environmental conditions are often deemed unsuitable for sleep; (3) stress and anxiety over well-being and future demands serve to inhibit sleep; (4) individuals stay awake because of the need to function effectively almost instantaneously, since any period of confusion immediately on awakening from sleep seriously interferes with performance.

The thrust of our current research, therefore, has focused on providing information concerning the factors thought to preclude prophylactic napping. The first studies involved assessing the frequency of napping by young adults; the individual differences in napping ability and the benefits derived from napping; behavioral, physiological, and psychological aspects of habitual nappers and non-nappers, including circadian rhythms; the effect of naps on performance both at awakening as well as some time later; and the effects of sleep-conducive and sleep-hostile environments on the ability to nap and derive benefits

from it. The bulk of our findings from these studies are contained in subsequent sections of this report.

We believe the data we present in this report provide important and new information on the nature of nap sleep, and its relationships to fatigue and effective functioning. Before detailing our studies and results, however, it is appropriate to review the scientific literature concerned with sleep, sleep loss, naps, and effective functioning in both laboratory and field studies.

B. Review of Relevant Literature.

1. The Natural Occurrence of Napping.

Sleep length and schedules are subject to large individual differences in adult populations. While within individuals the length of nocturnal sleep during the first half of adulthood is relatively constant, averaging a decline of about 30 minutes from 18 to 50 years of age (Tune, 1969; Webb, 1971), there is considerable variation among adults' sleep requirements. For example, Webb (1971) found that slightly more than half of over 4,000 college students averaged nightly sleep durations either longer or shorter than the normative 7 to 8 hours. Such variability in adults' sleep length is even more conspicuous when napping is considered.

Napping appears to be a particularly common way by which young adults of military age, with flexible schedules, complement their nocturnal sleep. Depending on whether surveys or sleep logs are used, and how the questions are asked, between 50% and 85% of the college population nap at least once a week (Lawrence, 1971; Webb, 1975; White, 1975; Evans, Cook, Cohen, Orne, & Orne, 1977; Kunken, 1977). Such a high occurrence of napping in these studies of college students is especially important since college students generally have time schedules that are more flexible -- in terms of scheduling sleep -- than the typical 9 to 5 work environment. Among young adults who do nap, afternoon naps are the most common, and the average duration is generally from one-half hour to a little over an hour.

Approximately 45% of the young adult population we surveyed in an earlier study (Evans & Orne, 1975) reported napping rarely or never. Most of these non-nappers report that they do not nap due to lack of available time. In this regard, it is worth noting that Webb (1975) reported a low frequency of napping in a 20-year-old non-college working population. These data seem to indicate that the likelihood of napping in young adults is primarily affected by the opportunity for this activity during working hours.

While napping is common in young adults, it is not uncommon even in the mid-adulthood working population. For example, from a study of 509 British adults who maintained sleep charts for 56 days, Tunc (1969) reported the mean number of naps across the 8 weeks averaged between five and seven for 40- to 60-year-old adults. Nap frequency increased to well over once a week as age increased to 80 years old.

Napping, therefore, appears to be a natural part of many adults' sleep regimes, especially when schedules permit it. There are, however, some important differences we have found between individuals in the purposes served by napping. Two primary reasons for napping seem common: (1) napping to compensate or replace sleep loss; (2) napping for reasons apparently unrelated to sleep need. Naps that serve to replace sleep loss are replacement naps, while naps unrelated to sleep need are termed appetitive naps (Evans et al., 1977). Both types of naps have implications for theories of sleep, as well as for the application of napping to problems of sustained operations.

a. Replacement naps. Napping to supplement the sleep debt as a result of missed nocturnal sleep is the most common reason for napping in approximately 75% of all military-age young adults who nap at least once a week. These nappers report that their naps are satisfying, and they nap only when they feel tired. Sleep diary data are congruent with this claim, and reveal that they nap either after experiencing a shorter than usual night's sleep, or sometimes in anticipation of sleep loss (Evans & Orne, 1975; Evans et al., 1976). The implication is that naps serve to compensate the individual for lost sleep.

Replacement napping clearly suggests that naps serve a restorative function, be it physiological or psychological. Such a suggestion is an extrapolation of a homeostatic or restorative theory of sleep; that is, napping is seen as reducing the need to sleep, and replenishing the potential for sustained wakefulness. This perspective predicts that nap frequency should be negatively related to the length of nocturnal sleep (such that shorter nocturnal sleep is associated with napping); and that the bulk of individuals who nap should do so only when they feel tired due to a truncation of typical nocturnal sleep.

Our initial survey and sleep diary data provide some confirmation of the latter prediction, and other research lends additional support for napping in relationship to sleep debt. White (1975) and Evans and Orne (1975) found that the frequency of daytime naps in college students is indeed negatively correlated with the length of their nocturnal sleep, and positively correlated with the variability of their nighttime sleep.

Similarly, studies of nightshift workers find that while they have decreased amounts of continuous morning sleep (the time of day they typically sleep), they also have an increased number of afternoon naps (Tepas, Stock, Maltese, & Walsh, 1978).

Thus, it appears that among individuals who nap, the most common reason is to replace lost sleep. While nearly three quarters of all young adult nappers nap primarily for this reason, and though we believe all nappers are capable of replacement napping when necessary, there appears to be a significant minority of nappers who frequently nap for reasons unrelated to sleep need.

b. Appetitive naps. Among habitual young adult nappers, about 25% report napping even when they do not feel tired; that is, they appear to nap recreationally. Their sleep diaries confirm that they nap regardless of previous or subsequent night's sleep (Evans & Orne, 1975). We have referred to these subjects as appetitive nappers, since they nap frequently and not primarily for restorative purposes.

Appetitive napping seems to fit more readily under an alternative theory of nap sleep function, namely, that napping is an aspect of an endogenous biological rhythm, and as such it is unrelated to sleep need reduction. In fact, Webb (1978a) has speculated that the endogenous sleep/wakefulness cycle is biphasic, that is, consisting of two sleep periods: one long nocturnal period, and a second brief afternoon period. As with nocturnal sleep, he argues that naps are a behavior control,

only in this case they aid the organism in avoiding the "torrid heat of midday." (Webb, 1978a; p. 316).

Webb (1978a) supports his claim for naps being an aspect of a circadian oscillator by noting studies showing that napping is a highly prevalent part of young children's (Reynolds & Malley, 1933) and older adults' (Webb & Swinburne, 1971) sleep as well as the majority of young college adults' sleep (White, 1975); that adults can readily go to sleep between 2 and 5 p.m. (Walker, 1972); that individuals in a time-free environment have a tendency to nap (Webb & Agnew, 1974b); that there is a predictable post-lunch performance decrement indicative of a "non-responding tendency" (Hockey & Colquhoun, 1972); that many animal species reveal intermittent or nap-like sleep (Ruckebusch, 1972); and that napping occurs in many human cultures and appears to be unlearned.

This theory sees nap sleep as appetitive, in the same way that sexual behavior is appetitive: it can be enjoyed, but if unavailable it is unlikely to damage the organism. While this may be the case, it is important to note that this may hold for naps only as long as adequate nocturnal sleep opportunities are available. When, as in the case of quasi-continuous performance, nocturnal sleep opportunities are curtailed, nap sleep may be an effective means of avoiding the debilitating effects of sleep deprivation. While Webb (1978a) concurs that replacement naps are related to sleep debt, he does not believe that sleep debt causes the naps. Rather, for Webb, naps in the face of sleep debt reflect an

increased sensitivity in an innate biological response system, namely, to sleep at midday.

Although appetitive napping appears to be unrelated to feelings of fatigue and nocturnal sleep need, it is possible that its refreshing effects are more a function of the cognitive changes associated with a period of non-wakefulness. That is, the appetitive napper may nap for cognitive benefits rather than physiological requirements, and such a nap may relate more to the functions served by taking a brief break (during wakefulness), than to the functions of sleep per se. Viewed in this way, the appetitive nap need not be part of an endogenous sleep/wakefulness cycle, but rather a coping mechanism utilized during prolonged periods of waking functioning.

Regardless of the teleological reasons for napping, current data show that there is a high incidence of napping in military age adults, particularly when work schedules permit it, and that most naps phenomenologically fulfill the individual's desire for sleep and aid in feelings of recovery from fatigue. While the theoretical issues continue to be important, the practical question of whether naps can be used to facilitate effective functioning in individuals otherwise deprived of desirable sleep opportunities remains to be determined.

2. Napping and Effective Functioning.

A number of studies of napping in relation to effective functioning have recently yielded information on the potential of naps to maintain or improve performance and mood. The questions addressed by these

investigations concern whether naps improve mood and functioning in non-sleep-deprived nappers; whether naps provide nappers with benefits beyond what bedrest might provide non-nappers; whether a few short naps are as effective as one continuous period of sleep in maintaining functioning; and whether naps are more effective in maintaining performance than bedrest and exercise over a 40-hour period.

a. Performance and mood following naps in non-sleep-deprived adults. Taub, Tanguay, and Clarkson (1976; see also Taub, 1977) assessed habitual nappers' simple auditory reaction times and subjective ratings of activation (mood) 20 minutes before and after 1/2-hour and 2-hour afternoon naps and a 2-hour wake control period. They found that relative to the control period of no sleep, nappers performed significantly faster on the reaction time task, and reported significantly greater activation following the naps, leading the authors to infer "that there is an identifiable increase in behavioral and subjective efficiency associated with customary episodes of afternoon sleep" (p. 216). They suggested that since their results were neither due to nap length (1/2-hour and 2-hour naps yielded similar improvements) nor to specific sleep stages within the naps, the increased capacity following naps was probably associated with the maintenance of a sleep/wakefulness cycle that included regular afternoon naps. Such a view would predict that just as habitual nappers derive benefits from naps, habitual non-nappers should derive benefits from afternoon waking bedrest, but not from naps. The critical variable in such a prediction is maintenance of the typical

sleep/wakefulness cycle. For habitual nappers this includes napping, while for non-nappers an equivalent period of waking rest should be as helpful as a nap is for a napper.

Recently, Bertelson (1979) tested this hypothesis as well as attempting a replication and extension of the Taub et al. (1976) study. She had 20 habitual nappers and 20 habitual non-nappers complete auditory and visual reaction time tasks, a cognitive addition task, and mood adjective checklists before and after a 1-hour nap period for the nappers and a 1-hour wake bedrest period for the non-nappers. She found that both groups experienced significant improvements in positive mood from pre- to post-nap, but neither group showed significant improvements in any performance parameter. Thus, her data suggest that in terms of mood, bedrest is as beneficial to non-nappers as napping is to nappers. While Bertelson's (1979) data suggest that the benefits from napping observed by Taub et al. (1976) might be due to maintenance of a regular sleep/wakefulness cycle (regardless of whether it includes napping or non-napping), additional napping data from Taub, Hawkins, and Van de Castle (1978) indicate this may not be the case.

Using a design similar to earlier work, Taub et al. (1978) had nappers nap at two times of the day, 180° out of phase with each other. Following both morning (0935-1135) and evening (2135-2335) naps, their habitual nappers again showed the predicted increments in simple reaction time performance, and improvement in mood relative to wake control periods at the same time of the day. Their subjects were habitual nappers

who reported napping at irregular times of the day. It is difficult to see how these data, juxtaposed with earlier findings (Taub et al., 1976), support the value of maintaining a regular sleep/wakefulness cycle. An alternative interpretation would be that naps increase the effective functioning of nappers regardless of when, during the daytime, they are taken.

Nevertheless, a number of questions remain concerning the effect of napping versus not napping on non-sleep-deprived nappers and non-nappers. Except for our original work (Evans & Orne, 1975) described below, no study has yet compared performance, mood, sleepiness, and physiological characteristics of confirmed nappers and non-nappers during both wake (control) periods and various laboratory nap conditions, in order to determine what aspects of napping and not napping are associated with consistent individual differences in napping behavior and the ability to derive benefits from naps. Moreover, we know of no study reporting data on the sleep/waking patterns and circadian patterns of both nappers and non-nappers.

b. Napping versus short sleep and no sleep. While studies of non-sleep-deprived nappers and non-nappers should provide some understanding of individual differences in napping patterns and the benefits of napping, such studies do not specifically address the practical question of whether napping can be more effective in maintaining functioning than either a reduced continuous sleep period or no sleep at all. Some recent laboratory studies have investigated these issues.

Hartley (1974) compared signal detection performance on a vigilance task (known to be sensitive to sleep loss) over four days for subjects on three different experimental sleep/wakefulness regimes: one continuous 8-hour sleep period per day; one continuous 4-hour sleep period per day; and three 80-minute nap periods during each day. He found that while both the nap group and the 4-hour continuous sleep groups performed below the 8-hour (no sleep loss) group, the 80-minute nap group performed better than the 4-hour group, and in some ways (e.g., false alarm rate) the nap group was similar to the 8-hour group.

Since the nap group and 4-hour sleep group averaged the same amount of total sleep time per 24-hour period, * and the nap group outperformed the 4-hour group, it seems reasonable to conclude that the napping regime is a more desirable alternative for maintaining functioning than allowing the same amount of reduced continuous sleep. Hartley (1974) attributed the superior performance in the nap group relative to the 4-hour group to the fact that the distribution of sleep (albeit only 80 minutes at a time) into three periods of the day served to reduce the amount of prior wakefulness between sleep episodes and thus maintain the vigilance response criteria typically used by individuals who are not sleep-deprived.

*This is conservative, since logically, three periods of sleep onset in the 80-minute group is likely to have shortened their total sleep time (per 24 hours) relative to the 4-hour group.

A totally sleep-deprived group was not included in Hartley's (1974) study, and thus, it is unclear how much better the nap group and 4-hour sleep group performed in comparison to a no sleep group. Lubin et al. (1976; see also Johnson et al., 1977), however, compared a fragmented or napping sleep schedule during 40 hours to both bedrest and exercise sleep-deprivation conditions. The nap group was allowed to sleep 60 out of every 220 minutes, while the bedrest group rested and the exercise group exercised during the 60 minutes.

Relative to the sleep-deprived groups, the nap group showed no impairment on six of eight measures, including a vigilance task, an addition task, mood, and oral temperature. This is especially impressive since the nap group had no continuous period of sleep beyond an hour, and averaged only 3.7 hours total sleep out of 24 hours. Furthermore, the nap group did not show an alteration of the infrastructure of nocturnal sleep on the recovery night, while the bedrest and exercise groups did; leading Moses, Hord, Lubin, Johnson, and Naitoh (1975) to conclude "that naps presumably have some recuperative value, at least in terms of preserving the normal amounts and distribution of sleep stages during recovery sleep (p. 632)." This is important, since many studies assess the efficacy of fragmented ("napping") sleep regimes solely on the basis of the amount of alteration in recovery sleep, presumably indicative of sleep debt accumulation, rather than directly assessing performance (e.g., Weitzman, Nofzinger, Perlow, Fukushima, Sassin,

McGregor, Gallagher, & Hellman, 1974; Carskadon & Dement, 1975).*

Thus, it appears that, at least within the laboratory, napping can serve to maintain a level of functioning significantly above performance after bedrest without sleep, exercise without sleep, and a reduced single period of sleep. In order to appreciate how effective napping might be in a quasi-continuous performance situation, it is necessary to examine what is known about sleep deprivation, and the efficacy of short sleep periods to sustain functioning in field situations.

3. The Effects of Disruption of Sleep/Wakefulness Cycles.

There are three broad ways in which the typical 1 to 2 ratio of the sleep/wakefulness cycle is likely to be disrupted during quasi-continuous performance. These involve displacing the sleep period to any part of the 24 hours outside of its normal placement time (displaced sleep); truncating the absolute amount of sleep available by limiting sleep length and/or sleep opportunities (partial sleep loss); and eliminating sleep altogether (total sleep loss).**

a. Displaced sleep. Taub and Berger have published numerous papers assessing performance and mood following acute variations in

*Bonnet (1980) has provided some evidence that recovery sleep infrastructure changes may be more related to sleep loss than performance and mood alterations.

**We recognize that these categories are to some extent operational distinctions that need not be mutually exclusive. For example, displaced sleep can result in partial sleep loss.

in the monophasic night sleep patterns of young adults (e.g., Taub & Berger, 1973a, 1973b, 1974a, 1974b, 1976a, 1976b; see also Taub, 1978). Their findings indicate that displacing, shortening, or lengthening nocturnal sleep produces decrements in vigilance and addition performance, and increases negative mood states. Unfortunately, and somewhat surprisingly, they excluded from their experiments subjects with a history of daytime napping -- the very individuals who would be most likely to have the ability to utilize napping to compensate for the nighttime sleep alterations. Moreover, a recent investigation by Knowles, Cairns, and MacLean (1978) failed to replicate the vigilance performance deficits found for the displaced sleep conditions, though they were able to show the expected time-of-day effects on performance and sleep infrastructure.

Insofar as the Hartley (1974) and Lubin et al. (1976) studies also involved performance assessments following displaced and fragmented (napping) sleep they provide information in this area. These studies reveal that while slight performance deficits may accompany the displaced sleep regime, the overall performance and mood of the napping groups was well above that of subjects undergoing various forms of reduced continuous sleep and total sleep deprivation.

b. Total sleep loss. Though the subjective, emotional, and performance effects of total sleep loss (no sleep from 24 to 240 hours) are universally acknowledged, it has been difficult to document these changes because of the complexity of motivational variables that maximize

performance when an individual is the subject of a relatively brief test in a psychological experiment (Williams, Lubin, & Goodnow, 1959). The effects of total sleep deprivation on performance have been effectively reviewed by Naitoh (1969), and subsequently updated by Johnson and Naitoh (1974). In general, there are complex interactions between the total amount of deprivation and the kind of tasks employed to measure performance impairment.

Performance impairments consist mostly of lapses in responding, yielding decreases in speed or accuracy or increased variability of response (Williams et al., 1959; Naitoh, 1969). Long, complex vigilance tasks have usually been most effective at demonstrating these lapses (Wilkinson, 1968); but tasks involving a heavy load on short term memory (Williams, Gieseeking, & Lubin, 1966), and reaction time measures have also proven to be sensitive to prolonged sleep deprivation.

More recently, short (10-minute) serial and choice reaction time tasks have been found to be sensitive to as little as one night's sleep deprivation (Lisper & Kjellberg, 1972; Glenville, Broughton, Wing, & Wilkinson, 1978). Of course, the traditional long, complex tracking-vigilance tasks have also been documented to reveal performance impairments after only one night's sleep loss (Wilkinson, Edwards, & Haines, 1966; Hockey, 1970; Hord, Lubin, Tracy, Jensma, & Johnson, 1976; Collins, 1977; Glenville et al., 1978), as have subjective estimates of sleepiness and mood states (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973; Moses, Johnson, Naitoh, & Lubin, 1975; Roth, Kramer,

& Lutz, 1976; Glenville & Broughton, 1978; Maltese, Walsh, & Stock, 1978). Subjective feelings are important indicants of sleep loss since they generally occur before decrements in performance or in physiological and neurological functioning can be documented, and thus may serve to reveal subtle sleep debt accumulation.

c. Partial sleep loss. While it is clear that man does not function well with prolonged total sleep loss, it is less clear what the effects on subjective well-being and performance are when a person is subjected to acute or chronic partial sleep deprivation (Johnson & Naitoh, 1974). This is especially relevant, since even if prophylactic napping were used during quasi-continuous performance, some partial sleep deprivation would still occur, though prolonged total sleep loss would be avoided.

From our perspective, partial sleep deprivation studies are relevant insofar as they provide an approximation of how effectively short periods of sleep maintain performance. The partial sleep deprivation literature includes studies of both gradual and abrupt restriction or fragmentation of sleep schedules, and the theoretical perspectives that motivated these studies are as varied as the designs employed.* Across studies of gradually reduced nocturnal sleep (Johnson & MacLeod, 1973; Mullaney et al., 1977); abruptly reduced nocturnal sleep (Webb & Agnew,

*Other partial sleep loss studies have been concerned with depriving individuals of specific stages of sleep. These studies do not appear relevant to our concerns. As Johnson (1973), after summarizing the available literature, aptly concluded, there is little evidence that waking performance bears any direct relationship to specific sleep stages.

1965; Wilkinson et al., 1966; Hamilton, Wilkinson, & Edwards, 1972; Webb & Agnew, 1974a); fragmented sleep (Curtis & Fogel, 1972; Lubin et al., 1976); and combinations of fragmented and reduced sleep (Rutenfranz, Aschoff, & Mann, 1972; Hartley, 1974) results consistently indicate that most performance can be maintained with 60%-70% of the usual amount of daily sleep, even when this limited sleep is obtained in short fragmented periods. Moreover, with less than half the amount of usual sleep, performance is not halved but generally maintained at or near full capacity. There are, however, broad individual differences in sensitivity to partial sleep loss, particularly with regard to the length of time individuals can maintain adequate performance and morale on reduced sleep schedules.

4. Studies of Napping during Simulated Continuous Military Operations.

Recently, studies have begun to appear that involve assessment of effective functioning during many days of sustained military operations for individuals experiencing total and/or partial sleep deprivation (Francesconi, Stokes, Banderet, & Kowal, 1978; Opstad, Ekanger, Nummestad, & Raabe, 1978; Bugge, Opstad, & Magnus, 1979; Hasl m, 1981).* What makes

*We have opted not to review the field studies of continuous operations for 1 to 2 days (Banks, Sternberg, Farrell, Debow, & Daihamer, 1970; Haggard, 1970; Ainsworth & Bishop, 1971) because the length of operations in these studies is relatively brief, and the results reveal that for 48-hour periods, personnel are able to motivate themselves to perform many military tasks effectively, though individual differences in ability to withstand this acute deprivation are important. Our interest in the recent studies stems from their more realistic duration and the extent of the measures taken.

these recent studies especially interesting is that they involve military personnel as subjects engaged in military performance in a field setting designed to simulate various forms of continuous operations. Though these investigations do not specifically address the efficacy of prophylactic napping, they nevertheless provide important field data on the performance, mood, morale, general functioning, and tolerance of personnel to sleep loss, and various restricted sleep regimes. The results of these studies closely parallel and confirm what has thus far been reviewed regarding the effects of altered sleep/wakefulness regimes on functioning, but further dramatize the effectiveness of short periods of sleep toward maintaining performance during sustained operations.

Opstad et al. (1978) assessed performance (vigilance, reaction time, code test, sorting test, command memory, shooting test), mood (Profile of Mood Stages), and clinical symptoms in 44 young male cadets of the Royal Norwegian Military Academy participating in a ranger training course. Two strenuous combat courses, one 4 days, and the other 5 days were carried out with three groups in each exercise: a total sleep loss group, a group allowed 3 hours sleep in the middle of each course, and a group allowed 6 hours sleep in the middle of each course. The 4-day course amounted to 92 hours of sleep deprivation for the no sleep group, 89 hours for the 3-hour sleep group, and 86 hours for the 6-hour group. The 5-day course

involved the same amounts of sleep deprivation plus an additional 24 hours.*

Relative to the total sleep loss group, the groups allowed a little sleep in the middle of each course showed significantly fewer performance and mood deficits following their brief sleep, with the 6-hour group doing somewhat better than the 3-hour group. Of course, even in the groups allowed only a few hours sleep in 4 days, performance was generally below baseline levels. Nevertheless, in terms of effective functioning, even a small amount of sleep appeared to be clearly advantageous compared to no sleep at all. Bugge et al. (1979) have recently replicated these findings, again using Royal Norwegian Military Academy cadets undergoing a ranger training course, and further found very high correlations ($>.80$) between mood and cognitive performance (for group mean data) during sleep deprivation, suggesting that mood is a good predictor of performance rhythm (circadian) under stress (sleep loss, heavy physical work, and caloric deficit).

*Interestingly, the authors of this paper comment that "the cadets managed to get short naps estimated by the cadets themselves to amount to 1-3 hours totally, during the course" (p. 1066). While the authors do not provide data on the occurrence and length of these naps in the totally and partially sleep-deprived groups, it is likely that the cadets, once they were thoroughly exhausted, utilized napping when possible to adjust to the continuous performance demand of the combat course. One can only speculate how much more effective their functioning would have been if they had been trained to use every sleep opportunity for prophylactic napping even prior to becoming extremely fatigued.

Haslam (1981) has presented data on two field studies conducted with the British armed services. The first of these involved 68 members of a parachute regiment (mean age 21 years) divided into three groups: a no sleep group, a group allowed 90 minutes of sleep every 24 hours, and a group allowed 3 hours of sleep every 24 hours. The first field study required the soldiers to perform 5 exercises for 9 consecutive days, during each of which a defensive position was prepared and occupied. Data included: military tests (vigilance shooting, grouping capacity, weapon handling), cognitive tests (encoding/decoding, map-plotting, short term memory, logical reasoning, Stroop Test), visual acuity tests, EEG and assorted physiological and biochemical measures, and subjective ratings of mood, sleepiness, military effectiveness, etc. (by both the participants and observers). Soldiers could withdraw themselves from the exercises at any time and could be withdrawn if they were judged by physicians to be unfit to continue.

By the fourth day of the 9-day study, all of the totally sleep-deprived soldiers had withdrawn from the exercise, unable to continue. Half of the 90-minute sleep group made it all the way to day 9, compared to most (91%) of the 3-hour sleep group. The total sleep loss group had profound decrements in vigilance shooting, weapon handling, all of the cognitive tasks, as well as flattened circadian curves, intense sleepiness, negative mood, and an EEG indicative of unavoidable light sleep onset episodes. By day 3 without sleep they were judged by the observers to be militarily ineffective!

In contrast, the 90-minute and the 3-hour sleep groups were less impaired on vigilance shooting and encoding tasks, had no weapon handling impairment, and experienced less sleepiness and more positive mood. This is especially impressive, since most of these subjects completed the full 9 days on the reduced sleep schedule. Their morale stayed fairly high, and they were judged to be generally militarily effective for the bulk of the 9 days. Not only did more of the 3-hour sleep group finish the study, but they also experienced less sleepiness. However, their performance on the military and cognitive tasks was not above that of the 90-minute sleep group. It would have been particularly interesting had the study included a group allowed 90 minutes of sleep twice a day (3 hours per 24 hours). Hartley's (1974) data would suggest such a group might do better than either of Haslam's (1981) reduced sleep groups, though, as Naitoh (1981) has shown, it might depend on where in the circadian cycle these sleep periods are taken.

In a second study, Haslam (1981) attempted to create a situation even more realistically approximating that found in continuous military operations. While the study again involved young soldiers engaged in a tactical field exercise (defensive position), this time, enemy soldiers were countered, and all subjects experienced the same sleep/wakefulness regime -- 3 and 3/4 days without any sleep, then 4 hours of sleep a day for 5 and 1/4 days. The measures employed basically consisted of the various military, cognitive, physiological, and subjective measures used in the first study. The question this study sought to answer was whether

a reduced sleep schedule could compensate for the effects of prior total sleep loss.

The results showed that soldiers experienced the expected deterioration in performance and mood after 3 days without sleep, and that overall 4 hours of sleep per 24-hour period could indeed reverse most of the debilitating effects of prior sleep loss. After a day or two with 4 hours sleep, performance improved significantly, unscheduled (uncontrolled) sleep episodes diminished, and alertness increased. Observers rated soldiers' military effectiveness as significantly improved following the 4-hour sleep periods. These findings are rather convincing evidence that within an individual, sleep deprivation effects can be created by total sleep loss, then ameliorated with less than a full quota of sleep.

Taken together, these field studies during continuous tactical operations provide a remarkably consistent set of data that agrees with extensive laboratory work on the effects of total and partial sleep loss. However, a number of additional points are made by the military studies that serve to emphasize the profound psychological consequences of sleep loss during continuous operations, as well as the interaction of both exogenous and endogenous forces with the effects of sleep loss.

a. Exogenous factors interacting with sleep loss effects during quasi-continuous operations. For a sleep-deprived soldier engaged in continuous operations, environmental factors can clearly increase or reduce the effects of sleep loss. For example, Haslam (1981) found that most of the soldiers who dropped out of the first study did so on the

day it rained continuously, feeling they could no longer function effectively (rain gear was not provided).^{*} Conversely, cognitive performance improved after sleep-reduced subjects were allowed to dry out and warm up.

Similarly, aspects of the environment that would usually be considered fairly trivial become relevant to the mood of fatigued soldiers during sustained operations. In the second of her investigations Haslam (1981) observed that subjects' Total Mood Disturbance scores were lowest the day they were told the washing facilities were broken, leading Haslam to remark "that the withdrawal of a privilege from a tired soldier can result in a deterioration in mood far greater than that induced by sleep loss itself (p. 56)." Thus, minor issues come to loom large and can have profound effects on the sleep-deprived soldiers' attitudes, even in the context of an otherwise well-integrated unit with unusually high overall morale.

The presence and behavior of leaders can, to some degree, also serve to enhance or attenuate sleep loss effects on mood and performance. Perhaps not surprisingly, Haslam (1981) noted that totally sleep-deprived soldiers were more likely to drop out of a study after the Platoon Commander dropped out. Conversely, the visit of a VIP to the shooting range during testing following 3 days without sleep was associated with an upswing in performance scores that day, presumably due to increased alertness. Finally, Haslam (1981) noted that a relaxed leadership style

^{*}Severe temperatures are also important in this regard.

emphasizing exhortation rather than commands was the best way to deal with tired soldiers suffering the cumulative effects of sleep loss.

Thus, there appears to be good evidence that in the field, exogenous factors can, at least for brief periods, exacerbate or attenuate the pervasive effects of sleep loss on performance and mood. Though variables outside of the subject are important to understand, their effects are nevertheless likely to be more transient than endogenous factors.

b. Endogenous factors interacting with sleep loss effects during quasi-continuous operations. There are a number of known endogenous parameters that can affect mood and performance and when they are considered in the context of sustained operations, their effects can interact with those of sleep loss. Circadian fluctuations in physiological, behavioral, and subjective measures are among the more pervasive internal factors capable of potentiating the effects of sleep loss (Johnson & Naitoh, 1974). While circadian dips in performance, for example, normally occur between 0300 and 0600 hours (Hockey & Colquhoun, 1972), they are strikingly more consistent during total sleep loss. Partial sleep loss due to fragmented sleep, on the other hand, does not appear to alter these circadian effects beyond their normal influence (Curtis & Fogel, 1972; Moses, Lubin, Naitoh, & Johnson, 1978).

Field studies also confirm the relationship between circadian variations and sleep loss effects. Haslam (1981) found that most cognitive performance benefited from 4 hours sleep. Logical reasoning, however, showed some impairment that was greatest at 0545 hours,

suggesting an unavoidable circadian dip. Bugge et al. (1979) specifically studied circadian rhythms in mood and performance in cadets undergoing sleep deprivation during a ranger training course. They noted that during the ranger course, relative to baseline and recovery periods, performance and mood declined and circadian variations were more pronounced (40% versus 30%-20%) as sleep loss progressed. They suggested "that the mixed effects of sleep loss and physical exhaustion potentiate the fluctuations of natural circadian rhythm (p. 667)."

Naitoh (1981) recently reported a study assessing the effects of sleep loss, and naps taken at different times of the circadian cycle, on mood, physiology, and performance in young sailors. After 45 hours without sleep, a 2-hour nap from 0400 to 0600 was followed by diminished functioning and negative mood, that appear to be primarily associated with normal circadian drops at such hours. In contrast, naps taken from 1200 to 1400 produced improved functioning on some parameters, and did not yield the kinds of performance decrements found for naps taken during the circadian trough. Such data suggest that, at least for sleep-deprived individuals, naps taken during the circadian trough fail to reverse the inevitable consequences of sleep loss; further, the effects of circadian variations in functioning are such that performance following the nap is actually worse than performance preceding it. Clearly, in sleep-deprived individuals at least, the effect of napping on mood and performance interacts with the circadian cycle.

Physical work load (energy expenditure) is another endogenous factor that can interact with both sleep loss effects and circadian rhythms, as was noted by Bugge et al. (1979). Though different theories of sleep function would predict very different relationships between sleep and energy expenditure, studies of varied work load coupled with sleep deprivation have been rare. The most pertinent question relevant to quasi-continuous performance is whether increased work load would exacerbate sleep loss effects. Since Haslam's (1981) subjects did not have a high work load, her data do not bear on this issue. However, a recent study by Bonnet (1980) showed that a 16-hour march by Marines (not sleep-deprived) resulted in performance and mood decrements approximately equivalent to 40 hours of sleep loss. It would be surprising indeed if increased work load did not further shorten -- either physiologically or psychologically -- individuals' resistance to total sleep loss, and perhaps also partial sleep loss.

An aspect of work load that deserves additional consideration is the amount of stress inherent in the circumstances of a given period of sustained operations. Physiological arousal resulting from stress is an expected phenomenon of quasi-continuous performance. Common biochemical indices (urinary 17-hydroxycorticosteroids) of stress have been shown to be greatly affected when military combat operations were sustained (no sleep) over periods of 39 to 48 hours, providing stress-inducing work loads are maintained. Francesconi et al. (1978) studied artillery fire direction center teams during a sustained simulated combat scenario,

and found increased evidence of stress as sleep deprivation progressed.*

In contrast, sleep deprivation studies without stress-inducing work loads have not found increased biochemical indices of stress (Tyler, Marx, & Goodman, 1946; Murawski & Crabbe, 1960; Haslam, 1981).

Situational uncertainty also appears to affect indices of stress, as well as interacting with sleep loss. Francesconi et al. (1978) found that uncertainty (over how long operations may have to be sustained) produced even greater levels of stress in a fire team. Conversely, Haslam (1981) found that soldiers who had been allowed only 3 hours of sleep every 24 hours for 9 consecutive days actually showed a spurt of improvement in performance the 9th day, presumably associated with their knowledge that day 9 was the last day of sustained operations. Furthermore, finding that increased levels of stress accompany situational uncertainty suggests that, during sustained military operations, slack times may be available for sleep, but personnel may have trouble going to sleep because of anxiety over the anticipation of heavy work load.**

*Even if performance is generally maintained during quasi-continuous operations, physiological and subjective indices of stress may reveal a cost for the demands of sustained operations. In studies of flight crews who experienced partial sleep loss (or no sleep loss) increased 17-hydroxycorticosteroids, hypothermia, increased post-mission sleep, and feelings of fatigue indicated a cost was paid for the effective performance (Harris, Pegram, & Hartman, 1971; Hartman, 1971; Hale, Hartman, Harris, Miranda, & Williams, 1973; Hartman, Storm, Vanderveen, Vanderveen, Hale, & Bollinger, 1974).

**Naitoh, P. Personal communication, March 6, 1979.

Assuming that personnel involved in quasi-continuous exercises do go to sleep for varying periods, they might have considerable trouble performing immediately upon being awakened from sleep. Both Opstad et al. (1978) and Haslam (1981) noted that when cognitive functioning was tested within 5 minutes of awakening, performance was significantly poorer than either before sleep or 15 to 30 minutes after sleep. This performance decrement at awakening appears to be ubiquitous, and has been shown to occur with a wide variety of performance measures. These include: simple reaction time (Okuma, Majamura, Hayashi, & Fujimori, 1966; Williams, Morlock, & Morlock, 1966); complex reaction time (Goodenough, Lewis, Shapiro, Jaret, & Sleser, 1965; Scott, 1969; Seminara & Shavelson, 1969; Dinges, Orne, Evans, & Orne, 1981); grip strength (Jeanneret & Webb, 1963; Tebbs & Foulkes, 1966); steadiness and coordination (Wilkinson & Stretton, 1971); visual-perceptual tasks (Scott & Snyder, 1968; Scott, 1969); memory (Stones, 1977; Akerstedt & Gillberg, 1979); time estimates (Carlson, Feinberg, & Goodenough, 1978); complex behavior simulation tasks (Langdon & Hartman, 1961; Hartman & Langdon, 1965; Hartman, Langdon, & MacKenzie, 1965; Seminara & Shavelson, 1969); and a host of cognitive tasks like mental addition, subtraction, cancellation, clock reversal, decoding, and reasoning (Pritchett, 1964; Scott, 1969; Wilkinson & Stretton, 1971; Fort & Mills, 1972; Tebbs, 1972; Dinges et al., 1981; Haslam, 1981).

While gross motor tasks, such as reaction time, recover relatively quickly, some type of performance decrements have been shown to recover relatively slowly, that is, persisting for up to 20 minutes after awakening. This is especially evident in more complex cognitive and behavioral tasks such as mental arithmetic and pilot simulation (e.g., Pritchett, 1964; Hartman & Langdon, 1965; Wilkinson & Stretton, 1971). Haslam (1981) has speculated that this post-sleep performance decrement may last even longer in individuals suffering sleep loss. She also suggested that the decrement might have been attenuated in her study had there been an arousing stimulus, such as a threatening or demanding situation. We have been unable to find data on this point. Indeed, little is known regarding ways to modify the post-sleep performance decrement. While it is possible that a threatening situation might result in faster and more accurate performance upon awakening, the anticipation of a threatening situation might involve enough stress to inhibit sleep altogether in individuals who have not gained volitional control over sleep onset (unless they are totally exhausted).

5. The Control of Sleep Onset.

Learning to nap prophylactically would likely involve both psychological and behavioral changes in any personnel not already habitually oriented toward compensatory sleeping at available times. An efficient use of slack time opportunities to nap would require learning to go to sleep in a relatively brief period of time. Thus, we fully expect that for some individuals sleep onset training would be necessary.

Recently, there has been increased interest in the problems of sleep onset in the treatment of insomnia, where sleep onset difficulties can form a part of the symptomatology (Kales & Kales, 1974). Reports of treatment of sleep onset difficulty by behavior therapy and biofeedback techniques have provided evidence for the efficacy of these approaches in decreasing sleep onset latency (Ribordy & Denney, 1977; Bootzin & Nicassio, 1980). For example, some studies have shown that feedback of EMG muscle tension can significantly improve the onset latencies in chronic insomniacs (Stoyva, 1973). However, similar results have been obtained with hypnosis (Graham, Wright, Toman, & Mark, 1975), and relaxation training without feedback (Borkovec & Fowles, 1973). It would appear that stimulus control instructions and most relaxation training procedures (progressive relaxation, autogenic training, self-hypnosis, meditation, and biofeedback) can have significant effects on shortening sleep onset in insomniacs (Bootzin & Nicassio, 1980).

However, our primary interest is the control of sleep onset in normal individuals who are not insomniacs. Thus, as we noted above, there are broad individual differences in the ability to nap at various times. Our own recent factor analytic studies of subjective sleep patterns have suggested that there are several unrelated dimensions underlying habitual sleep patterns (Evans, 1977a). For the present program, the most important of these was one tentatively identified in terms of the voluntary control of sleep processes: some subjects consistently

report they fall asleep easily at night and can sleep in a wide variety of unusual surroundings. Habitual nappers consistently score higher on this dimension than non-nappers. Thus, while we may not understand the mechanism whereby one can voluntarily turn on and off sleep processes, it does seem that the capacity to do so is an individual characteristic, with nappers having greater control over this capacity than non-nappers.

Of particular interest in our own work was the isolation of a subgroup of habitual non-nappers who also seemed to have the capacity to control sleep processes (Evans, 1977b). These were non-nappers who did not nap, primarily because they felt they did not have time and that napping would interfere with other activities, as opposed to a second much smaller group of non-nappers who avoided naps because for them there were unpleasant physical and mental consequences. The first group of non-nappers not only could exert more control over sleep processes but were more hypnotizable than those non-nappers who did not report such control.

In sum, our own data have suggested that there are a considerable number of individuals who already have a high degree of control over sleep onset and a far greater number who have the potential for learning this skill more easily than is generally recognized. A number of procedures (including self-hypnosis or relaxation techniques, bio-feedback, and some form of stimulus control, mental set instructions) show promise in facilitating an individual's control over sleep onset

and may therefore be relevant in implementing prophylactic napping on a broad scale.

Perhaps equally important as individual training in relaxation and control of sleep onset is a modification of the behavioral context in which napping is expected to occur during quasi-continuous work schedules. Prophylactic napping requires a framework wherein sleep discipline becomes a legitimized and appropriate activity. Personnel would have to be motivated to nap during slack times, and would have to perceive the nap as a desirable event. Social facilitation of prophylactic napping would then also occur in the context of sustained operations.

6. Summary of Relevant Literature.

Those aspects of the sleep literature directly relevant to prophylactic napping have been reviewed. Napping appears to be a common phenomenon among the majority of young adults who have schedules that permit it, with replacement (compensatory) naps being the most common form of napping. Laboratory studies have been reviewed documenting improvements in performance and mood following naps in non-sleep-deprived individuals who nap regularly; showing the advantage of a few short naps over one reduced continuous sleep period in partially sleep-deprived adults; and demonstrating the utility of naps in preventing many of the deficits found in totally sleep-deprived subjects.

It appears that as little as one 24-hour period without sleep can deleteriously affect mood and performance in some individuals, and a number of consecutive days without sleep will yield progressive

deterioration in positive mood states, vigilance, reaction time, and cognitive performance, with concomitant increases in negative mood and involuntary sleep onset for most individuals. Partial sleep loss studies, including abrupt and gradual sleep reduction and fragmented sleep, support the conclusion that performance can generally be maintained with reductions of up to 40% in total sleep time, though sleepiness and negative mood may increase. Thus, there appears not to be a linear relationship between amount of sleep loss and the degree of performance impairment. Even as little as 3 hours sleep in the middle of 113 hours of sustained activity can improve functioning significantly.

Recent studies of psychological, behavioral, and physiological functioning in military personnel undergoing sustained operations for up to 9 days confirm the laboratory data on the effects of partial and total sleep loss. Total sleep deprivation so profoundly diminished functioning during continuous operations that within 4 days motivated personnel fully recognized their inability to function effectively, and independent observers confirmed the ineffectualness even sooner. However, a single 90-minute sleep period each day significantly lessened the sleep loss effects, thus permitting somewhat more effective functioning for more days. A 3-hour period of sleep each day had even greater salutary effects. Moreover, following 3 days of sustained operations with accompanying sleep deprivation and cumulative drops in performance and mood, 4 hours of sleep a day thereafter reversed much of the deteriorated functioning.

While sleep loss can account for much of the diminished capacity found in personnel engaged in sustained operations, other factors can further exacerbate declining performance and mood. Stress, heightened work load, diurnal variations, and hostile environmental conditions are frequent aspects of continuous military operations that will affect functioning regardless of sleep debt. Nevertheless, when the negative effects of these factors are combined with the cumulative effects of sleep loss, especially total sleep loss, performance and mood deteriorate profoundly, making effective functioning nearly impossible for most individuals, and ultimately leading to involuntary sleep at inopportune times. Despite the presence of these factors, the elimination of sleep loss effects alone should go a long way toward maintaining effectiveness.

Prophylactic napping was conceptualized as a potentially realistic way in which personnel could prevent or at least postpone the effects of sleep loss by napping during slack times and in advance of anticipated periods of sustained operations. Thus, as individuals who are already partially sleep-deprived are more sensitive to further sleep loss, it would be surprising indeed if individuals who have had some sleep were not more resistant to the effects of subsequent sleep loss. The efficacy of naps to enhance the capacity to function, particularly under conditions of limited sleep opportunities, would seem to be a reasonable alternative to the cumulative effects of total sleep loss.

However, individual differences in napping ability, as well as hostile sleep environments, stress, and attitudes toward napping suggest

that prophylactic napping will necessarily involve training some individuals to control sleep onset. The most promising techniques would appear to be combinations of relaxation procedures and stimulus control instructions. Further, modeling and social facilitation of napping in the particular context in which prophylactic napping is to occur are important. Thus, a combination of training, a restructuring of attitudes towards napping, and appropriate legitimization are likely to be needed for prophylactic napping to become an operationally useful technique.

C. Overview of Studies.

A review of the napping literature and studies of sleep loss reveals that no investigation has yet determined how effective naps are in maintaining functioning if they are taken in advance of sleep loss -- prophylactic napping. While naps appear to be a way many individuals cope with precedent or subsequent sleep loss, and it is clear that naps can have beneficial consequences, it is less certain whether they are beneficial for everyone.

Though we have emphasized the agreement among studies of short sleep periods in terms of maintenance of performance, it is important to note that definitive conclusions cannot be drawn from the body of literature on changes in sleep patterns, fragmented sleep, or the potential of naps to alleviate fatigue, without taking into account the naturally occurring differences among individuals' sleep/wakefulness patterns, including the ability to nap. Indeed, Johnson and Naitoh's (1974) extensive review of the consequences of sustained operations places considerable emphasis on individual differences in response to sleep loss, in typical sleep patterns, and the maintenance of effective functioning.

Because of the implications of individual differences for the utilization of naps to facilitate performance in the absence of desirable sleep opportunities, it was important to first establish the relevance of individual differences to the ability to nap and derive benefits from it. Thus, our initial studies sought to determine the frequency of napping in

young adults; individual differences in napping ability; psychophysiological characteristics of naps; benefits derived from naps; and the effect of naps on performance and mood both immediately after the nap as well as some time later.

The studies of napping ability and consequences were carried out on non-sleep-deprived habitual nappers and non-nappers, in a sleep-conducive environment. However, we recognized that implementation of a napping regime, particularly prophylactic napping during continuous operations, would necessarily require individuals to nap in sleep-hostile environments. Consequently, we also investigated the effects of naps in non-sleep-deprived nappers and non-nappers attempting to nap in an environment unconducive to sleep. We were interested in comparing individuals' reactions to these naps with the brief daytime sleep in the sleep-conducive environment, to determine if the ability to nap and the consequences of a nap vary not only along individual difference parameters, but also as a function of the napping environment.

The survey studies used to investigate the incidence and type of napping patterns in the military age population necessarily employed many hundreds of young adults. The laboratory phase of the studies used selected samples of these young adults, and included extensive physiological, subjective, and behavioral measures. However, we also included sleep diary and circadian data in our studies in an effort to validate survey reports of napping patterns in relation to sleep loss,

and to determine the degree to which circadian oscillators might relate to napping ability and the effects of napping. The following sections in the report detail our procedures, results, and their implications for future work.

Following the investigations of nappers and non-nappers in varying nap environments, we plan to conduct a study specifically designed to efficiently test the effect of prophylactic napping in an acute sleep deprivation paradigm. Such a study logically follows the investigation of individual differences in napping pattern. The group of individuals participating in the prophylactic napping study is intended to come from the category of replacement nappers (who typically nap to compensate for sleep loss).

Finally, following the prophylactic napping study, we plan to determine the most effective means of teaching non-sleep-deprived individuals to gain volitional control over sleep onset. The ability to sleep at will and ignore future uncertainty, danger, or unpredictable work demands is a significant asset to the effective functioning of any individual required to sustain performance in the face of stress.

III. THE CURRENT STUDY OF NAPPING

A. Procedure.

1. Survey and Classification of Subjects.

Our studies of napping have focused on the normal, healthy, young male and female adult college population. The age range of these subjects is typically 18 to 35 years, and is therefore comparable to the age of a significant proportion of military personnel. Moreover, the general variability of college students' schedules results in some flexibility in sleep/wakefulness patterns, and thus provides a population where broad individual differences in napping behavior are common.

In order to gain some insight into the patterns and purposes of napping and non-napping, as well as replicate earlier findings, we surveyed 956 young adults using a questionnaire called the Survey of Subjective Sleep Patterns (SSSP; Evans & Orne, 1975; see copy in Appendix I). This questionnaire had been developed and used in our earlier work (Evans & Orne, 1975), and these 956 respondents were in addition to 946 college adults surveyed in our original study. The full procedural details for soliciting individuals to complete this survey are identical for both the original and current study. A detailed description of the survey methods and the SSSP itself is contained in our earlier progress report by Evans and Orne (1975). Only those aspects of the SSSP

survey dealing with napper classification in the current study will be described here.*

The first section of the SSSP contains questions on nocturnal sleep patterns. The last question of this initial SSSP section concerns how often the individual catnaps during the day. If a subject responds that he naps sometimes, usually, or always, he is instructed to complete the blue (i.e., napper) section of the SSSP. If a subject responds that he rarely or never naps, he is requested to fill in the green (i.e., non-napper) section of the questionnaire. The blue and green sections are sealed, and completion of one precludes completing the other.

a. Nappers. The blue napping section of the SSSP contains questions on an individual's frequency of napping, the temporal characteristics of the naps, the positive and negative consequences of the naps, as well as the circumstances under which he is most and least likely to nap. A subject is considered a current napper if he naps at least once a week, and finds naps generally very satisfying.

Beyond this broad categorization we have found that nappers can be classified into two types based upon four possible responses to the SSSP question "Do you nap even when you do not feel very tired?" Subjects who respond negatively (i.e., possibly no or definitely no) to this question are labeled replacement nappers, since they indicate they nap

*These classification criteria are identical to those originally developed and reported by our laboratory (Evans & Orne, 1975; Evans et al., 1977).

primarily when tired, presumably to relieve a sleep debt. Nappers who respond affirmatively (i.e., possibly yes or definitely yes) to the question are termed appetitive nappers, since they consistently report napping regardless of subjective fatigue, and thus presumably largely independent of nocturnal sleep variability. These subcategories of nappers appear to be consistent proportions of the young adult population, and thus provide a basis for investigating individual differences in napping patterns and consequences.

b. Non-nappers. Completion of the green non-napping section of the SSSP serves to classify a subject as a current non-napper. Since there appeared to be many reasons for not napping, we further separated non-nappers based upon their reasons for not napping, and their non-napping history. We specifically sought to isolate a group of non-nappers who not only did not nap, but also avoided napping because it had negative effects upon them. Thus, in order to be classified as a confirmed non-napper, a subject had to indicate in response to SSSP questions that he or she has not taken naps since childhood (excluding transient periods such as illness), finds naps generally unpleasant, and either unpleasant mental and/or physical aftereffects are the reason for avoiding napping.* Non-nappers not meeting these criteria were classified as reject non-nappers, and though their SSSP responses were

*Questions concerning unpleasant aftereffects (general, mental, and physical) were answered on a 5-point scale where 1 = irrelevant and 5 = definitely applies. A response of 3, 4, or 5 was required to be considered affirmative.

analyzed to determine why they did not nap, they were not studied as a group in the laboratory.

2. Qualification of Subjects for the Laboratory Phase.

Of the 956 subjects surveyed, subsamples of replacement nappers, appetitive nappers, and confirmed non-nappers were contacted and asked to participate in the laboratory phase of the study. In addition to being qualified by questionnaire criteria, subjects had to be between 18 and 31 years of age and in good health.* The total number of surveyed subjects meeting either the napper or non-napper qualification criteria as well as the age and health criteria were 479. Of these, 67 subjects, 36 males and 31 females, were run in the laboratory study.

Since we sought to compare the effects of naps in nappers and non-nappers who represented vastly different patterns and purposes of napping, we considered it essential to further confirm our SSSP classification of subjects volunteering to participate in the study. An interview procedure employed and described in our original study (Evans & Orne, 1975) was again used to confirm subjects' SSSP classification. This consisted of all subjects being interviewed by an experimenter blind to their SSSP classification, and subsequently classified by him into either replacement napper, appetitive napper, or confirmed non-napper categories.

*Over 95% of the subjects were between 18 and 24 years of age.

Of the 67 subjects run, 57 (85%) were classified into the same broad category (i.e., napper or non-napper) by both the SSSP and interviewer. Of these 57, 31* (46% of 67) were also classified into the same specific category (replacement napper, appetitive napper, confirmed non-napper) by both criteria.** Only these 31 subjects were included in the data analyses reported here. These included 11 replacement nappers, 11 appetitive nappers, and 9 confirmed non-nappers.

Throughout the data collection and analyses, experimenters handling the laboratory sessions were blind to subjects' sleep and nap patterns, and classification. Subjects were reimbursed at a rate of \$2.50 per hour for time spent in the laboratory, and \$1.10 for transportation to and from the laboratory.

*The number was actually 32, but one non-napper subject had a radically altered sleep/wakefulness cycle during the study, including considerable sleep deprivation due to studying. The schedule was so atypical for this individual that the subject was excluded from analysis.

**The majority ($n = 25$, 71%) of the 35 subjects not meeting the conservative double classification criteria were categorized as nappers by both the SSSP and interviewer, but these two disagreed on the specific type of napper. Eight subjects met the SSSP criteria of appetitive nappers but were categorized as replacement nappers by the interviewer. Since we know that appetitive nappers are also able to replacement nap when the need arises, these 8 discrepancies are understandable. However, another 17 subjects were replacement nappers by the SSSP, but considered appetitive nappers by the interviewer. Replacement nappers are not considered capable of appetitive napping, though these data indicate this may not be the case. Examination of the interviewer's comments indicated that most of these 17 discrepancies resulted when the interviewer decided the subject napped often enough to preclude pure replacement napping.

3. Experimental Design.

Figure 1 shows an outline of the experimental design of the study. Over a 30-day period, subjects were invited to attend four separate laboratory sessions, with each session being between 3 and 5 hours in duration. Whenever subjects' schedules permitted, the first three sessions (DAYS 1, 2, & 3) were scheduled 1 week apart, while the fourth session followed 2 weeks after the third. Informed consent was obtained prior to each of the four laboratory sessions. The first (DAY 1) and fourth (DAY 4) sessions served as wake control conditions, while the second (DAY 2) session required napping in an optimal, sleep-conducive environment, and the third (DAY 3) session involved napping in a somewhat sleep-hostile environment.

The order of laboratory nap DAYS 2 and 3 was not counterbalanced since any adaptation effects to the laboratory would be expected to work against the experimental hypothesis of validating napper vs. non-napper differences in the ability to nap in a hostile environment. That is, adaptation effects from the DAY 2 optimal nap session should increase the likelihood of sleep occurring in the subsequent DAY 3 hostile environment. Moreover, it was expected that the effect that the DAY 3 environment would have on various nap parameters would be opposite to those typically found for laboratory adaptation.

Whenever possible all sessions for a given subject were run in the afternoon, between noon and 6:30 p.m., and nap DAYS 2 and 3 were always started during this period. Subjects were run individually, and

4-HOUR LABORATORY SESSIONS		NON-LABORATORY MEASURES *	
(Performance, sleepiness, and temperature are measured before and after each of the laboratory sessions.)		SLEEP DIARY	MULTIPLE CIRCADIAN MEASURES
			TIME (DAYS)
DAY 1	Wake Control Period		1
		1-1	2
		1-2	3
		1-3	4
		1-4	5
		1-5	6
		1-6	7
DAY 2	Nap in Optimal Environment	1-7	8
		2-1	9
		2-2	10
		2-3	11
		2-4	12
		2-5	13
		2-6	14
DAY 3	Nap in Non-optimal Environment	2-7	15
		3-1	16
		3-2	17
		3-3	18
		3-4	19
		3-5	20
		3-6	21
		3-7	22
		4-1	23
		4-2	24
		4-3	25
		4-4	26
		4-5	27
		4-6	28
		4-7	29
DAY 4	Wake Control Period	5-1	30
		3-1	

* Non-laboratory measures are data collected by subjects at home. The circadian measures include oral temperature, Tayer Activation Scale, and body movement.

Figure 1. Schematic layout of the 30-day study. DAYS 1 through 4 were laboratory sessions, while sleep diary and circadian measures were collected at home between laboratory visits.

within each subject the specific starting hour for the four laboratory sessions was as close as possible, to minimize confounding circadian effects.

During the 30-day period from DAY 1 to DAY 4 subjects completed a detailed sleep diary (see Appendix II) at home each morning, and for 2 weeks between DAYS 3 and 4 they also recorded multiple daily measures of oral temperature and subjective arousal outside the laboratory. Subjects were reimbursed additionally at a rate of \$1.00 a day for completing the diary, and \$1.00 a day for completing the temperature and arousal ratings.

4. Laboratory Sessions.

a. DAY 1. The first visit to the laboratory included a detailed description of the study, additional sleep questionnaires, practice on the Descending Subtraction Task (DST) and Random Number Generation procedure (RNG), and subjects were given the sleep diary to complete each morning for the subsequent 30 days. Though this session included a 60-minute period preceded and followed by physiological and subjective activation measures (and thus provided a wake control period to compare to the effects of nap DAYS 2 and 3 on activation indices), the DAY 1 session served primarily to acclimate the subjects to the laboratory, the investigators, and the subjective and performance dependent variables.

b. DAY 2. One week after DAY 1, subjects returned to the laboratory for the first afternoon nap session (DAY 2), which took place in a sleep-conducive (i.e., optimal) environment typical of most sleep

laboratories. This involved napping in a bed in a dark, temperature-controlled, sound-attenuated room. It was emphasized prior to the nap sessions that even if an individual did not nap, the data would be of interest, since the study sought to investigate both sleep and rest. This was deemed necessary to allay any anxiety subjects (especially non-nappers) might have had concerning their ability to sleep in the afternoon. Subjects were encouraged to maintain their usual sleep patterns throughout the study, and especially the night before each nap day. Prior to and following the naps subjective, performance, and physiological measures were recorded at specific time points.

Figure 2 displays an outline of measurements taken before and after both experimental nap DAYS 2 and 3. Performance, subjective arousal, and oral temperature were recorded four times: twice prior to the beginning of each 60-minute nap period (about 1 hour before, and immediately before), and twice following each nap period (immediately after, and about 45 minutes after). The purpose of repeating measures both before and after the napping session was to clarify the time course of effective functioning preceding and following a nap. Though the same sequence of measurements was taken during both wake control sessions (DAYS 1 and 4), measurements occurred only twice, once immediately before and once immediately after the 60-minute wake periods. In addition to the measures recorded before and after the naps, standard sleep recordings (Rechtschaffen & Kales, 1968) were taken during the nap periods.

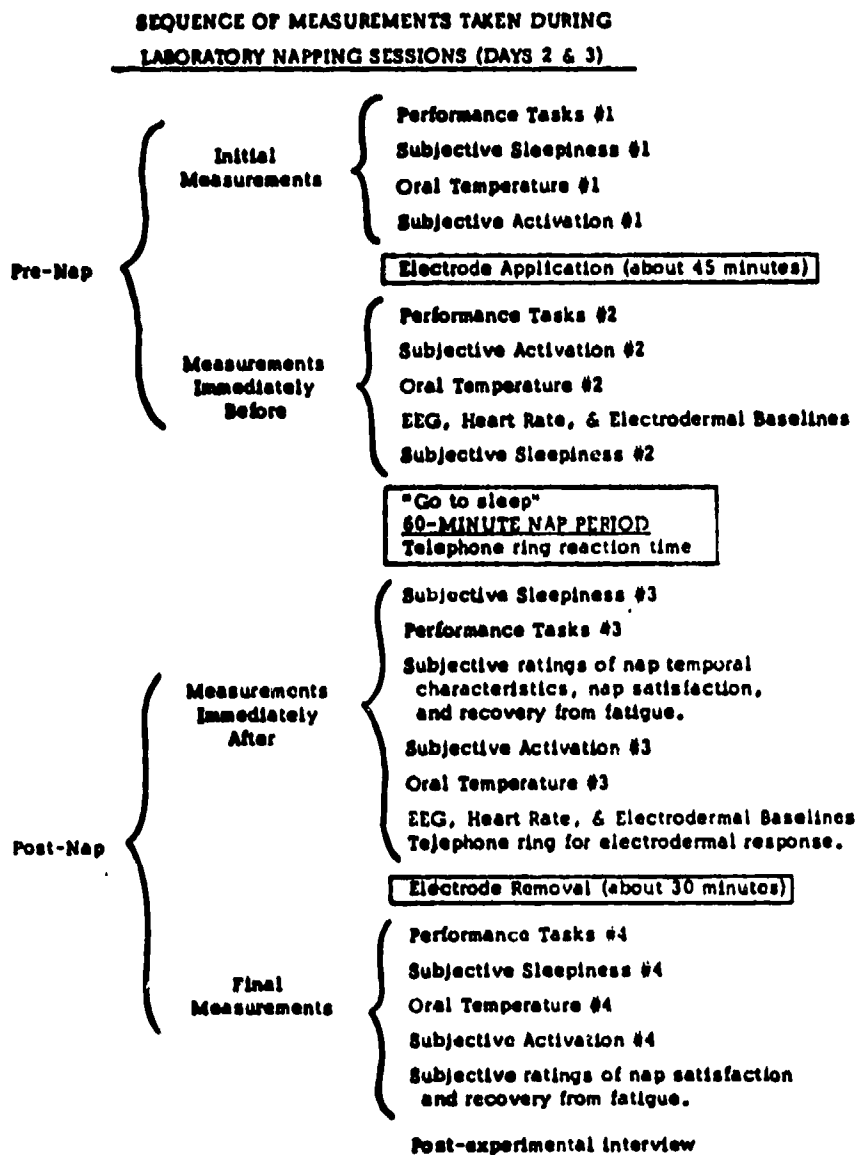


Figure 2. Types and sequencing of measurements taken during laboratory naps.

While subjects knew in advance that they would be given an opportunity to nap on DAYS 2 and 3, they were not told the amount of time that would be available for the nap; further, temporal cues were removed from the environment. In fact, on both nap days subjects had 60 minutes to nap from the time they were told they could "go to sleep now" to the signal terminating the nap. They were told that a telephone situated next to them would ring (72 dB spl) signalling the end of the nap.

Though DAY 2 involved many more measures than our earlier napping work (Evans & Orne, 1975), it nevertheless contained those parameters necessary to permit a replication of our earlier findings concerning differences in the naps of nappers and non-nappers. The additional measures allowed us to extend the comparisons to performance and subjective activation domains. Finally, DAY 2 also served as a baseline for comparing the effects of a hostile nap environment on the sleep and functioning of nappers and non-nappers.

c. DAY 3. Nap DAY 3 took place 1 week after nap DAY 2, with an effort being made to schedule it on the same day of the week and at the same time of the afternoon as DAY 2. While for a very few subjects this was not possible due to schedule changes, it is noteworthy that for all subjects the average time difference between the start of DAY 2 and DAY 3 nap periods was only 30 minutes.

Nap DAY 3 was identical to DAY 2 in all procedural aspects, the major exception being the environment in which the nap was taken. For DAY 3 subjects were told they would be provided an opportunity to nap

in an environment more similar to what they might encounter at home or in the dormitory. Specifically, they were asked to nap in a different room from DAY 2, while sitting up in a semi-reclined lounge chair (with foot rest) with the light on. They were also told that unlike the DAY 2 room, the DAY 3 room was not sound-attenuated and consequently they would hear some noise from the corridor upstairs and outside the building. In order to keep the auditory stimuli of DAY 3 constant, a tape recording of common building sounds, such as footsteps, paging, doors closing, etc. (14 different types of sounds in all), was prepared and played through a speaker concealed in the wall above the ceiling during the entire three hours the subject was in the DAY 3 room. The occurrence of each sound during the nap period was registered on a channel of the polygraph along with a description of the sound. There were approximately 48 periods of sound in the 60-minute nap period of DAY 3, varying in duration from a few milliseconds (door slam) to 2 minutes (computer teletype), and ranging in intensity from 40 dB (conversation) to 62 dB (hospital cart being dragged) with a median intensity of 50 dB (adjusted for 46 dB ambient noise level of room). Sounds seemed to be coming from a corridor on the floor above. Post-experimental inquiries conducted by two independent experimenters at the end of DAY 3, as well as at the end of DAY 4 when the entire experiment had been completed, indicated that only two subjects questioned whether the sounds were natural occurrences. Finally, DAY 3 differed from DAY 2 in that the telephone

bell on DAY 3 was increased in intensity to 93 dB to permit assessment of an intense stimulus on performance at awakening.

Since the use of napping in the field by military personnel would almost certainly involve sleeping for brief periods in somewhat alerting environments, we considered it necessary to determine what effects an alerting environment like DAY 3 was likely to have on napping in non-sleep-deprived habitual nappers and non-nappers. We fully expected that whereas confirmed non-nappers would have difficulty in napping on DAY 3, appetitive nappers would have the least difficulty. Replacement nappers presented the real challenge in prediction, since on both DAYS 2 and 3 we were asking them to nap without necessarily depriving them of nocturnal sleep. While we anticipated they would nap on DAY 2, we were hopeful, though less certain, about their ability to nap on DAY 3. The fact that habitual nappers generally score higher on the control of sleep dimension than non-nappers (Evans, 1977a) would suggest that replacement nappers might be able to fall asleep in an alerting environment. However, when the sleep-hostile nature of the DAY 3 environment and the lack of sleep deprivation are considered, it seemed doubtful whether replacement nappers would be able to sustain sleep on DAY 3.

DAY 3 thus provided both a more realistic napping environment, as well as an opportunity to investigate the relationships among physiological, performance, and subjective parameters under experimental conditions that were likely to alter one or more of these data domains when compared to naps in an optimal environment.

d. DAY 4. Two weeks elapsed between DAY 3 and the final laboratory session, DAY 4, during which the oral temperature and subjective activation circadian data were collected by subjects at home. Upon returning to the laboratory for DAY 4, subjects turned in this data as well as their sleep diaries. Like DAY 1, DAY 4 involved no nap, but rather required subjects to complete non-sleep-related questionnaires during a 60-minute wake control period that was preceded and followed by performance trials, oral temperature measurements, and completion of subjective activation forms. The session was ended with an extensive debriefing covering the entire study.

DAY 4 permitted us to compare hypothesized pre-nap to post-nap data changes found on nap DAYS 2 and 3, with possible changes in data across a 60-minute wake control period. Such within-groups comparisons were considered necessary to determine what effects nap sleep vs. a quiet period of wake activity at the same time of day had upon data parameters. To assume that all changes observed from pre- to post-nap are the result of sleep, without determining if they occur with the mere passage of time, would have severely limited the scope of any conclusions regarding the functions of naps in young adults.

5. Data Collected.

a. Performance measures.

(1) Reaction Time (RT). The reaction time measure employed was somewhat more complex than a simple RT task. On nap DAYS 2 and 3 subjects were told that a telephone situated next to them would ring to

signal the end of the nap session. They were instructed to answer the phone as quickly as possible when it rang; the phone bell was arranged to ring continuously until the receiver was lifted. The time from bell onset to receiver pickup was electronically recorded on a polygraph channel and served as the RT measure. Fifteen minutes after each nap, at the end of a resting wake baseline period, the phone rang again, thus providing an RT from the wake condition following each nap. The DAY 3 bell was 21 dB (spl) more intense than the DAY 2 bell.

(2) Descending Subtraction Task (DST). The DST was specifically devised to tax the cognitive functioning of an individual for a relatively brief period of time. It can be carried out by a subject while lying in a bed in the dark, and it does not require the presence of the experimenter in the room. Thus, it allows testing within seconds of awakening. The subject is initially given a three-digit number such as 832. He is asked to repeat it aloud, then required to mentally subtract the number 9 from 832 and to say the remainder (823) aloud. The minuend now becomes 823, from which he is required to subtract 8. The remainder (815) is again said aloud. In this fashion the subtrahend progressively decreases by one until, having reached the value of 2, it returns to 9, and the series is continued in this manner. The subject continues until, at the end of 3 minutes, he is told to stop. The instructions emphasize repeatedly that the subject "should work as fast as possible and keep a steady pace. It is also important that you be as accurate as possible." A typical sequence of correct subtractions said aloud by a subject is as

follows: 832, 823, 815, 808, 802, 797, 793, 790, 788, 779, 771, etc. The subtractions themselves are done silently; only the answers are said aloud. With multiple trials, the starting number of the task is always different, and a large enough number is selected to assure that even the fastest subject cannot reach zero within 3 minutes.

Since the task clearly requires that the subject keep both the subtrahend and minuend in mind, and since both change after each response, a considerable load is placed on short term memory during the task. Subjects are encouraged to correct any of their responses if they think there are errors, but, in any case, to go on. Thus, if they get completely lost in a sequence, they are to guess where they are and continue. The task can be scored for speed (total number of responses), accuracy (total number of errors), or both speed and accuracy simultaneously (number correct per second). The DST shows a practice effect over the first nine trials that should be taken into account when small increments in performance are studied. The DST was performed four times on each visit to the laboratory, including 60 minutes and 5 minutes before each nap session, as well as less than 1 minute and 35 minutes after each nap session. In the post-experimental inquiry nearly all subjects commented on the task's difficulty.

(3) Random Number Generation (RNG). The random number generation task has been derived from our work on the measurement and deployment of human attention (Graham & Evans, 1977; Evans, 1978; Evans & Graham, 1980). The subject is asked to randomly produce numbers between

1 and 10 (inclusive) in time with a metronome at a rate of one per second. The task demands that the subject keep in mind the numbers he has generated in the past -- in order to avoid using any given number more than another, or repeating a number too frequently. A trial lasts for 2 minutes, and the randomness of a sequence of 100 consecutive numbers in each trial is computed by a computer program (see Evans [1978] for scoring details). The RNG task was given immediately after each DST trial on both nap days and wake control days.

b. Subjective measures.

(1) Behavioral sleep/wakefulness patterns. Detailed sleep diaries (see Appendix II) were kept by all subjects throughout the duration of the 30 days from laboratory DAY 1 to 4. A version of the 4-page daily diary was used in our previous napping studies, and includes questions concerning both sleep as well as waking activity, and thus provides crucial information on the characteristics of nap days and non-nap days in the larger sleep/wakefulness pattern. In addition, the diary provides important information on the sleep the night before laboratory nap days. Subjects were requested to complete the diary each morning, shortly after arising.

(2) Subjective activation. An Activation-Deactivation Adjective Checklist (AD-ACL) developed by Thayer (1967, 1970) was used to assess subjective activation. The scale yields four orthogonal factors, two of which are related to diurnal fluctuations in subjective arousal and sleepiness (Clements, Hafer, & Vermillion, 1976). Factors from this brief

checklist have been reported to be affected by afternoon naps in non-sleep-deprived subjects (Taub et al., 1976; Bertelson, 1979), as well as by sleep deprivation (Bohlin & Kjellberg, 1973). A short 20-item version of the AD-ACL was employed repeatedly throughout all laboratory sessions, both before and after naps, and subjects were requested to complete this version for two weeks, at home, five times a day (upon arising, noon, 3:30 p.m., 7:30 p.m., and bedtime) to provide information on circadian variation in subjective activation in nappers and non-nappers. The short AD-ACL form was printed on 4 x 6 inch colored cards which were bound into booklets of 75. Each card had typed atop it the date and time of day it was to be completed. A different colored card represented each of the five times per day, and thus cards were arranged so that if a subject missed a recording, a blank card was evident. Further, the colors of the cards matched the appropriate Tempa-Dot thermometer labels for time of day (to be described below), and each card had space for recording the oral temperature that accompanied it, as well as the exact time of day it was completed.

(3) Sleepiness. The subjective sleepiness scale we developed and used is similar to other traditional sleepiness scales (Hoddes et al., 1973). It consists of a 10-point scale where 1 is "wide awake" and 10 is "very sleepy." Sleepiness and tiredness were assessed repeatedly throughout all laboratory sessions.

(4) Nap satisfaction and recovery from fatigue. In an effort to study subjective fatigue in conjunction with physiological and performance

measures, we included a number of rating scales designed to assess nap satisfaction, recovery from fatigue, nap refreshedness, and subjective estimates of the temporal characteristics of the nap. These scales followed immediately after nap DAYS 2 and 3, and again approximately 40 minutes after the naps.

c. Physiological measures.

(1) Oral temperature. As a measure of physiological activation, body temperature displays a 24-hour circadian rhythm that is closely associated with sleep/wakefulness patterns, as well as subjective sleepiness and performance rhythms (Kleitman, 1963; Colquhoun, 1971). We recorded sublingual (oral) temperature frequently throughout laboratory sessions, each time sleepiness and subjective activation were assessed. In addition, we asked subjects to record their oral temperature for 2 weeks, at home, at the same five times of the day they completed the AD-ACL. While we used both a basal thermometer and 1-minute Tempa-Dot* thermometers in the laboratory, the subjects used only the disposable Tempa-Dots at home. Subjects were provided with Tempa-Dots labeled for each date and color-coded consistent with the AD-ACL page for time of day, and were asked to save and return the used thermometers to the laboratory on DAY 4 for verification purposes. The fact that the temperature could be conveniently obtained in 1 minute (while they completed the AD-ACL booklet), and that subjects were treated as

*Organon, Inc.

coinvestigators to collect the circadian data on their own outside the laboratory, combined to yield over 98% complete data.

(2) EEG and related sleep/wakefulness measures. Four channels of electroencephalographic (EEG), 2 channels of electrooculographic (EOG), and 1 channel of electromyographic (EMG) recording were made throughout both DAY 2 and DAY 3 60-minute nap sessions, as well as during a 5-minute resting wake baseline (eyes closed) prior to and after each nap period. EEG was recorded from frontal and occipital lobes. EOG was recorded from outer canthi, and EMG was recorded from the submentalis muscle. Electrode placement, recording parameters, and sleep/wakefulness stage scoring of the records were accomplished using standardized criteria (Rechtschaffen & Kales, 1968). These measurements permitted assessment of a wide variety of nap sleep characteristics including sleep onset latency, sleep stage proportions, changes in wake alpha activity, and sleep length.

(3) Electrodermal activity and heart rate. Electrodermal activity was recorded from the palmar surfaces of the first and second phalanges of the second finger of each hand, while heart rate (HR) was recorded from the wrists. Recordings occurred during the laboratory nap periods, at the same time other electrophysiological measures were recorded. Electrodermal activity and heart rate recordings were included for the purpose of providing additional information on napper vs. non-napper differences in responsivity to stimulation during sleep. Since the non-optimal surroundings nap included extraneous acoustic stimuli, as well

as a very low akening bell, it was of some interest to address the issue of activation during naps in an alerting environment.

B. Distribution of Napping in the Young Adult Population.

While most surveys of college populations reveal napping to be a prevalent aspect of sleep/wakefulness cycles for between 50% and 85% of young adults (Lawrence, 1971; Webb, 1975; White, 1975; Kunken, 1977), few attempts have been made to further delineate other dimensions of napping and non-napping behavior in this population. Consequently, our surveys* have focused on the frequency of napping, as well as the satisfaction with napping, the relationship between napping and feeling tired, the reasons for not napping, and the consequences of napping for habitual nappers and non-nappers.

1. Nappers.

Table 1 presents the distribution of napping and non-napping within a sample of 956 young adults. The data are further subdivided to reflect the proportion of individuals who fall into relatively discrete categories, based upon their napping frequency, satisfaction, and general sleep characteristics. Although reports of napping "sometimes, usually, or always" were given by 55% of those surveyed, more rigid criteria for classification as a qualified napper required that respondents indicate they nap at least once a week, find it generally very satisfying,

*The 956 subjects surveyed in the current study were solicited from psychology classes at the University of Pennsylvania, and were paid \$3.00 for completing a packet of questionnaires that included the SSSP. To minimize volunteer bias, every effort was made to encourage subjects to agree to fill out the questionnaires. Of the students present in the classes, 93% volunteered. By paying subjects in advance it was possible to obtain completed SSSPs from 97% of all volunteers.

TABLE 1

	N	Percent of total surveyed	
Total Surveyed	956	100%	
Total Nappers ¹	527	55%	
Qualified Nappers ²	428	(45%)	Percent of Qualified Nappers
Replacement Nappers ³	318	(33%)	74%
Appetitive Nappers ⁴	110	(12%)	26%
Total Non-nappers ⁵	429	45%	Percent of Confirmed Non-nappers
Confirmed Non-nappers ⁶	37	(4%)	9%
Reject Non-nappers ⁷	392	(41%)	91%

¹ Includes all those who responded that they nap "sometimes, usually, or always."

² Qualified nappers are those subjects who report napping at least once a week, find naps generally very satisfying, and do not report any sleep difficulties.

³ Replacement nappers report napping only when they feel tired.

⁴ Appetitive nappers report napping even when they do not feel tired.

⁵ Includes all subjects who responded that they nap "rarely or never."

⁶ Confirmed non-nappers report no regular napping since adolescence, report finding naps generally unpleasant, and report napping has unpleasant physical and/or mental aftereffects.

⁷ Reject non-nappers were respondents who had either napped regularly during adulthood (but were not now napping) and/or did not find napping unpleasant.

and do not report any sleep difficulties (nocturnally or otherwise). Even using these more stringent criteria, a high proportion -- 45% -- of all surveyed subjects qualified as nappers.

These 428 qualified nappers were subsequently subdivided into two napping categories: replacement nappers were those 318 respondents who indicated they napped only when they felt tired; and appetitive

nappers were the remaining 110 who reported napping even when not tired. This division separated qualified nappers into those who presumably napped in response to sleep need (replacement) vs. those who presumably napped for reasons unrelated to sleep need (appetitive).

Given these different reasons for napping, it seemed reasonable to expect that appetitive nappers were likely to nap somewhat more frequently than replacement nappers. We examined the reported frequency of napping in our qualified nappers, and as Figure 3 reveals, replace-

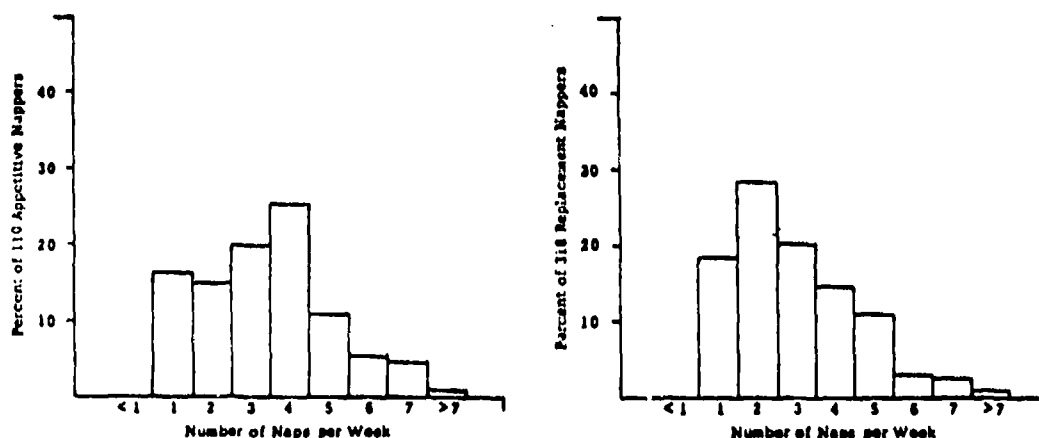


Figure 3. The proportion of appetitive and replacement nappers who nap at varying frequencies per week. Data are from a questionnaire survey.

ment nappers had a modal nap frequency of 2 per week compared to appetitive nappers' mode of 4 per week, though both groups showed a relatively even distribution of nap frequency between 1 and 5 times a week.

2. Non-nappers.

Having divided nappers along reasons for napping, we then focused on the 429 (45% of all respondents) non-nappers' reasons for not napping. We were especially interested in isolating a group of

confirmed non-nappers who avoided napping because it produced unpleasant consequences for them. Classification as a confirmed non-napper required that a subject report no regular napping since childhood, indicate that naps are generally very unsatisfying, and report that naps produce unpleasant physical and/or mental aftereffects. These criteria were basically the converse of those employed for qualified nappers. As Table 1 shows, the number of non-nappers who met the criteria, however, was a considerably smaller proportion of subjects. Four percent of all those surveyed -- 9% of all non-nappers -- were classified as confirmed non-nappers. The remaining 392 non-nappers were considered reject non-nappers.

While we sought to study confirmed non-nappers in the laboratory as a comparison group to qualified nappers for purposes of understanding the various consequences of napping, it also seemed important to examine the reasons reject non-nappers gave for not napping, since they constituted 41% of the population. Our survey questionnaire included a section that allowed non-nappers to check their major reasons for not napping.

Of the 392 reject non-nappers, 46% listed lack of time as the major reason for not napping, 25% indicated no need to nap (they got enough sleep), 15% reported they would not be able to fall asleep, and 11% felt napping produced some sort of unpleasant result, such as not being able to fall asleep at night. Clearly, the majority of these subjects -- 65% of all non-nappers -- report lack of time or lack of sleep need as the reasons they do not regularly nap, rather than inability or

negative consequences. This replicates our original finding (Evans & Orne, 1975) and seems to suggest that if time were available and there was a need to sleep, these reject non-nappers could learn to nap and derive benefits from it.

The survey data appear to support a view that napping is not only a frequent and satisfying aspect of sleep schedules for approximately half of all young college adults, but could, if time and circumstances permitted, potentially be included in the sleep patterns of most individuals. While the number of persons surveyed in this study was considerable, it is nonetheless striking that the group percentages reported in Table 1 regarding napper and non-napper classifications are all within 5% of a survey we conducted 5 years ago on 430 young adults (Evans & Orne, 1975). Thus, the proportion and distribution of napping patterns appear relatively stable within this population.

C. Results from Napping in Optimal and Non-optimal Environments.

1. Physiological Antecedents, Concomitants, and Consequences of Napping.

a. Nappers' and non-nappers' ability to nap. Based upon surveys and previous laboratory studies, we expected that nappers would have little difficulty falling asleep during the DAY 2 afternoon laboratory nap in the sleep-conducive environment, while some non-nappers would be unable to sleep. Indeed, the DAY 2 predictions were correct: four non-nappers, one replacement napper, and one appetitive napper did not sleep in the optimal environment.* When these DAY 2 proportions are combined with our earlier study, it is clear that more than 93% (40/43) of nappers are able to fall asleep in an optimal environment compared to 67% (14/21) of confirmed non-nappers ($p < .02$).

Since the DAY 3 alerting environment presented a greater challenge in terms of sleep inhibitors, and since subjects were not purposively sleep-deprived the night prior to the laboratory naps, we expected that few of the 9 non-nappers, some of the 11 replacement nappers, and most of the 11 appetitive nappers would be able to nap on DAY 3 -- although as we noted earlier, nappers' increased control over sleep would predict that proportionally more nappers than non-nappers would be able to nap in the alerting environment. Overall, fewer subjects were expected to sleep in the non-optimal environment of DAY 3.

*Sleep was arbitrarily defined as at least 3 consecutive minutes of stages 2, 3, or 4 sleep.

Surprisingly, as many subjects napped on DAY 3 as DAY 2.

Contrary to what we predicted, only two individuals from each of the three groups were not able to nap in the alerting environment of DAY 3. Specifically, more non-nappers and replacement nappers napped than expected. While the nappers' ability to nap in the sleep-hostile surroundings might be indicative of their control of sleep onset during the day, the finding that 7 non-nappers slept on DAY 3 is especially difficult to understand since only 5 of them napped in the optimal DAY 2 environment. Since we were surprised to find that so many subjects napped on DAY 3, we sought to understand the conditions that contributed to this, particularly among non-nappers.

Three possible factors could have accounted for this. First of all, the DAY 3 alerting environment may not have been sleep-hostile enough. This seems unlikely, given the radically different body position, lighting, and noise levels of the two nap days, and the fact that while two additional non-nappers napped on DAY 3 (vs. DAY 2), two fewer nappers napped on DAY 3. Moreover, on a questionnaire we developed called the Preference for Background Sounds or Silence (PBSS; see Appendix III), non-nappers scored significantly lower than both napper groups ($p < .05$), indicating less tolerance to background sounds. Thus, it is difficult to argue that the frequent extraneous noises throughout DAY 3 coupled with the other distractors were not sufficient to create an environment that confirmed non-nappers should have found totally un conducive to sleep.

Another explanation for non-nappers' sleep on DAY 3 concerns the effects of laboratory adaptation on the ability to nap. Since DAY 3 always followed DAY 2, non-nappers may have been more likely to nap on DAY 3, since DAY 2 acclimated them to the procedures of the naps. This view predicts that the 6 subjects who did not nap on DAY 2 should nap on DAY 3, yet only 2 did so, and 2 other subjects did the reverse, that is, napped on DAY 2, but not DAY 3. While the adaptation explanation of the DAY 3 napping cannot be fully discounted, some other dimension must have been involved that was capable of increasing the non-nappers' likelihood of sleep on DAY 3.

Analyses of sleep diary data for nocturnal sleep duration the nights immediately before nap DAYS 2 and 3 provided a third alternative to explain non-nappers' increased DAY 3 napping tendency. Within each napper group the average amount of sleep the night before DAY 2 was not significantly different from the sleep duration the night before DAY 3. However, non-nappers' pre-DAY 3 nocturnal sleep duration ($\bar{X} = 380$ minutes) was significantly shorter than their pre-DAY 2 nocturnal sleep ($\bar{X} = 330$ minutes, $p < .02$, two-tailed).

While the DAY 2 value was very close to their average nocturnal sleep ($\bar{X} = 410$ minutes) during the 30-day diary, non-nappers' duration of sleep the night before the nap in the sleep-hostile DAY 3 environment was nearly an hour and a half shorter than usual -- as a result of non-nappers falling asleep significantly later that night compared to their usual time (3:46 a.m. vs. 2:04 a.m.; $p < .05$).

It is noteworthy that subjects were told in advance that they were going to be asked to nap a second time in a dormitory-like environment (some sounds, light, and a chair), and were also requested to maintain their normal sleep schedules the night before the laboratory naps. Non-nappers appear to have suspected that they would have difficulty napping with extraneous sounds -- as indicated by their PBSS questionnaire responses -- without the added impetus of additional sleep need. Consequently, they may have complied with the demands of napping in the sleep-hostile environment of DAY 3 by increasing the likelihood of napping through partial sleep loss the night before.

In some respects, replacement nappers' nocturnal sleep before both laboratory nap DAYS 2 and 3 was similar to this non-napper DAY 3 situation. Replacement nappers had nocturnal sleep lengths before DAYS 2 and 3 that were close to what they averaged for diary nights before nap days at home, but significantly below what they averaged on nights before non-nap days at home. Appetitive nappers, on the other hand, had no significant differences in nighttime sleep durations the nights before laboratory naps, naps at home, and non-nap days. The details and implications of these data for understanding differences in the functions served by napping in replacement and appetitive nappers will be presented in a later section.

b. Nap sleep infrastructure in nappers and non-nappers. The fact that the majority of subjects in each group napped on both DAYS 2 and 3 permitted extensive analyses of nap sleep infrastructure between

groups within a nap day, as well as between nap days within groups. While a number of aspects of nap sleep staging and cycling were measured, only those findings that were clearly significant for a variety of measurements on a given dimension will be presented. Results that replicate or fail to replicate our earlier studies are noted, in an effort to focus on the most reliable differences.

(1) Sleep onset. Our earlier work had found that confirmed non-nappers took longer to fall asleep during an afternoon nap in a sleep-conducive environment than either replacement or appetitive nappers.* While the original finding was significant for both stage 1 and stage 2 definitions of sleep onset, neither measure replicated the result in the current study. Among the subjects who slept on DAY 2, non-nappers fell asleep as quickly as nappers, and among those subjects in each group who napped on both DAYS 2 and 3, sleep onset was not significantly different between DAYS 2 and 3. Thus, while fewer non-nappers are able to fall asleep during an afternoon nap, those that do appear to be able to fall asleep as rapidly as habitual nappers.

Since the current study asked subjects to take their first laboratory nap after an initial day of laboratory acclimation, and the earlier work required napping on the very first visit to the laboratory, it is likely that the sleep onset differences found in the earlier study were the result

*These analyses included only those subjects who actually napped, since averaging in those individuals who did not sleep during the 1-hour nap (sleep onset = 60 minutes) would misrepresent the actual sleep latency of non-nappers.

of poorer laboratory adaptation by non-nappers, or their greater anxiety over being asked to nap shortly after coming to the laboratory.

(2) Total sleep time and sleep efficiency. The nap periods provided subjects in the current study as well as in the earlier investigation were 60 minutes in duration, though subjects were not told how long they would have to nap. Despite the differences in sleep onset latency between nappers and non-nappers in the early study, the total sleep time (TST) from any definition of sleep onset did not vary significantly as a function of group in either the earlier or current study.

Physiological sleep efficiency (Total Sleep Time [TST] divided by total bed time, i.e., 60 minutes), however, was significantly lower for non-nappers in the earlier study -- as a result of their longer sleep onset latencies -- but did not replicate for subjects who slept on either DAYS 2 or 3 of the current investigation. Moreover, sleep efficiency was not significantly different on DAY 3 compared to DAY 2 for nappers and non-nappers who slept. Thus, for all subjects combined, sleep efficiency (from stage 2 onset) averaged 68% on DAY 2 and 64% on DAY 3, compared to a slightly lower 58% in the earlier study.

Physiological sleep maintenance efficiency (TST/time in bed after first sleep onset) was higher for non-nappers in the earlier study but did not replicate on either nap day of the present study. For all non-nappers and nappers combined, maintenance efficiency averaged 85% in the earlier study. Like sleep efficiency, maintenance efficiency was not affected by the DAY 3

environment, though this does not mean DAY 3 did not have effects on specific sleep stages.

(3) Sleep stages. Among the more intriguing differences found in our earlier work were the nap sleep infrastructure differences observed between nappers and non-nappers during naps in a sleep-conductive environment. Specifically, appetitive nappers appeared to have significantly higher amounts of stage 1 sleep during their nap than either replacement nappers or confirmed non-nappers. Given the nature of these differences, and the increasing amount of sleep literature suggesting specific stages of sleep are not reliably related to waking function, we thought it prudent to attempt to replicate these stage 1 differences, as well as thoroughly re-examine our earlier data for clues regarding the nature of the stage 1 differences. DAY 2 of the current study provided the sleep-conductive environment, and additional scoring of some of the earlier data allowed an extensive comparison between the studies.

Table 2 summarizes the major nap sleep infrastructure comparisons between groups in both studies. The column on the right indicates which differences were statistically significant (in the same direction) in both studies, and consequently, presents the replicated findings. While it is clear that significant differences were found in each study that were not replicated in the other, the stage 1 sleep difference between appetitive nappers and non-nappers did, clearly, replicate. This was the case for total minutes of stage 1 sleep, minutes of stages 1+2 sleep, and number of 30-second stage 1 sleep epochs. In addition, the

TABLE 2

Mean values of nap sleep infrastructure parameters for two studies of appetitive nappers (A), replacement nappers (R), and confirmed non-nappers (N) who slept during 60-minute afternoon nap periods in sleep-conducive environments.

Nap parameter	n =	Earlier study				DAY 2 of current study				difference replicated
		A	R	N	t-test results ¹	A	R	N	t-test results ¹	
Stage 2 sleep onset (mins)		13.5	11.6	25.4	N>R,A	11.1	11.9	12.9		
Mins. of stage 1 sleep ²		8.1	4.4	3.4	A>R,N	13.5	10.0	8.5	A>N	A > N
Mins. of stage 2 sleep		15.6	18.6	16.8		14.3	20.0	10.8	R>A,N	
Mins. of stages 1+2 sleep		24.9	23.0	19.9	A>N	27.8	30.0	19.3	A,R>N	A > N
Mins. of stages 3+4 sleep		16.0	19.0	13.1		22.1	16.9	27.2	N>R	
Mins. of REM sleep		0.0	0.0	0.0		0.0	0.0	0.0		
Total Sleep Time (TST) ³		32.2	38.0	30.0		40.6	41.8	41.6		
# stage 1 epochs (30-sec)		5.7	2.6	2.2	A>R,N	8.7	7.8	5.6	A>N	A > N
# awakenings after 1 onset		7.7	2.7	2.4	A>R,N	5.6	4.0	4.2		
# stage changes (30-sec) ⁴		11.4	7.3	6.2	A>R,N	16.8	18.0	11.6	A,R>N	A > N

¹ Differences significant at $p < .10$ (2-tailed) or less are reported.

² This includes stage 1 prior to stage 2 sleep onset.

³ Measured from stage 2 onset.

⁴ In the earlier study no distinction was made between stages 3 and 4 sleep, while in the current study this parameter included stages 3 and 4 fluctuations as well.

total number of 30-second stage changes after sleep onset was greater for appetitive nappers relative to non-nappers. These brief stage fluctuations accompany the increased light sleep of appetitive nappers, and may actually produce increased stage 1 in this group.* Highly consolidated sleep, like that of the non-nappers, would less often fluctuate to lighter sleep stages, and thus yield less light sleep.

Though replacement nappers' stage 1 values fell in between that of appetitive nappers and non-nappers in both studies, their values were more similar to that of appetitive nappers in the present study, and to that of non-nappers in the earlier work. Thus, replacement nappers' sleep

*Consistent with extensive literature, REM sleep was absent in these afternoon naps under 60-minute duration.

infrastructure can vary considerably in the degree to which it is consolidated, and the amount of light sleep. Appetitive nappers and non-nappers appear to show somewhat more characteristic patterns, at least for nap sleep in an optimal environment.

Nap sleep staging in a less sleep-conductive environment appears to have effects quite independent of group differences in sleep staging in a dark, quiet nap environment. Table 3 displays the results of sleep stage comparisons between groups, across nap DAYS 2 and 3 (includes only subjects who slept on both DAYS 2 and 3). The analysis of variance

TABLE 3

Mean minutes of nap sleep stage infrastructure parameters for 9 appetitive nappers (A), 9 replacement nappers (R), and 5 confirmed non-nappers (N) who slept during 60-minute afternoon nap periods on DAY 2 (sleep-conductive environment) and DAY 3 (alerting environment).

Nap parameter	Group	DAY 2	DAY 3	DAYS ¹ F _{1,20}	p <
Sleep onset (stage 2)	A	11.7	9.7	0.12	ns
	R	12.2	12.2		
	N	12.9	12.8		
Stage 1 sleep (total)	A	12.1	13.6	10.02	.005
	R	10.1	13.1		
	N	8.5	14.8		
Stage 2 sleep	A	14.2	15.7	3.12	ns
	R	19.0	20.6		
	N	10.8	18.3		
Stage 3 sleep	A	5.6	5.6	0.27	ns
	R	6.3	5.7		
	N	6.7	6.1		
Stage 4 sleep	A	15.7	10.2	9.65	.01
	R	11.6	8.9		
	N	21.8	8.5		
Total sleep time from stage 2 onset	A	39.6	37.4	1.16	ns
	R	41.8	40.4		
	N	41.6	37.3		

¹ This is the F for the main effect within groups (from nap DAY 2 to 3). No main effect between groups, nor group by day interaction on these parameters was significant ($p < .05$).

(ANOVA) F values are presented for the main effect of nap DAYS on each parameter, since these were the only significant effects.*

Examination of Table 3 reveals that while there were no significant differences across nap DAYS 2 and 3 in sleep onset or TST, sleep staging was definitely affected. The alerting environment of DAY 3 produced significantly less stage 4 sleep ($p < .01$), and reciprocally more stage 1 sleep ($p < .005$) than DAY 2, indicating that changing the nap environment from one that was highly sleep-conducive to one that was less conducive resulted in some deep sleep being exchanged for light sleep. Overall subjects averaged approximately 15% less stage 4 sleep and 10-15% more stage 1 sleep on DAY 3 compared to DAY 2, with non-nappers exchanging the most, that is, 30% of TST going from stages 4 to 1 (across DAYS).**

*To ensure that the ANOVA results were not obscuring important changes from DAY 2 to 3 for a specific group, we examined DAY 2 to 3 differences within each group using t -tests for paired comparisons. These comparisons fully support the main effects reported in Table 3, and do not suggest any differential effects on groups.

**As Table 3 reveals, the 5 non-nappers who slept had the greatest amount of stage 4 sleep on DAY 2, and the smallest amount on DAY 3. Conversely, they also had the least amount of stage 1 sleep on DAY 2, and the greatest amount on DAY 3. Despite the greater exchange by this group, no interaction was significant. However, when stages 1 and 2 are combined as a percent of TST, and compared to the percentage for stages 3 and 4 combined, an interaction term (groups by DAYS) approaches significance ($F_{2,20} = 2.70$, $p < .10$), as a result of non-nappers' nap sleep staging changing more than the napper groups. The fact that DAY 3 affected non-nappers' sleep staging somewhat more than nappers' is congruent with non-nappers' PBSS scores, which indicated they were more likely to be disturbed by extraneous noises than nappers.

These sleep stage results are remarkably close to the findings of a recently published Japanese study of daytime naps in a bed compared to naps in a chair (Ichihara, Miyasita, Inugami, Yatabe, Niimi, Ishihara, & Miyauchi, 1979). They examined sleep during the first 60 minutes of 2-hour naps in the morning (1000), afternoon (1300), and evening (1700), and found that naps in a chair significantly reduced the amounts of stage 4 and stage REM sleep, and increased the proportions of stage 1 and wakefulness. Their afternoon and evening nap data showed a 12-15% drop in stage 3+4 sleep, and an increase of 11-18% in stage 1 sleep for naps in a chair relative to naps in a bed. These exchange percentages are very near to the 10-15% values we found, and thus the two studies taken together leave little doubt that even subtle changes in the sleep-conduciveness of the nap environment can have demonstrable effects on sleep stage proportions. What causes these stage changes, and their relationship to subjective and behavioral consequences of napping are issues highly relevant to understanding the effects of napping under less than optimal environmental circumstances.

(1) Stage lability. The effect of the DAY 3 sleep-hostile environment on sleep staging suggested a more detailed look at sleep stage fluctuations during the naps might clarify the manner in which stage 4 sleep was being exchanged for stage 1 sleep. Since the DAY 2 between-group data showed that stage 1 increases during naps tend to be accompanied by increases in stage changes, detailed analyses of stage lability during the naps were carried out.

The results of those analyses are presented in Table 4. The dependent variables listed in the Table are the number of stage 1 epochs,

TABLE 4

Mean nap sleep lability parameters for 9 appetitive nappers (A), 9 replacement nappers (R), and 5 confirmed non-nappers (N) who slept during 60-minute afternoon nap periods on DAYS 2 and 3.

Nap parameter	Group	DAY 2	DAY 3	DAYS ¹ F _{1,20}	p <
Number of stage 1 sleep epochs (30-sec)	A	8.2	10.6	12.47	.005
	R	7.7	9.1		
	N	5.6	11.0		
Number of awakenings (15-sec) ² after stage 1 sleep onset	A	6.1	7.4	8.75	.01
	R	3.7	6.3		
	N	4.2	8.4		
Number of awakenings (15-sec) after stage 2 sleep onset	A	1.6	2.8	5.68	.025
	R	1.6	2.4		
	N	1.6	3.2		
Number of awakenings (45-sec) after stage 1 sleep onset	A	1.3	1.3	0.00	ns
	R	1.0	1.0		
	N	0.8	0.8		
Number of 30-sec stage changes ³	A	16.4	21.0	5.37	.05
	R	17.7	18.7		
	N	11.6	20.6		
Number of 60-sec stage changes ³	A	9.0	8.6	0.01	ns
	R	8.9	9.0		
	N	7.6	7.8		

¹ This is the F for the main effect within groups (DAY 2 to DAY 3). No main effect between groups, nor group by day interaction on these parameters was significant ($p < .05$).

² This includes all awakenings (determined by EEG criteria) of 15 seconds duration or longer.

³ Excludes fluctuations between stages 3 and 4 sleep.

the number of awakenings of various minimum lengths, and the number of stage changes throughout the 60-minute nap periods. As with the results presented in Table 3, Table 4 only displays the ANOVA F values for the main effect of nap DAYS, since both between-groups effects and interactions were nonsignificant for all lability measures.

The first effect reported in Table 4 is that the number of stage 1 sleep epochs of 30 seconds duration (or longer) is significantly increased on

DAY 3 relative to DAY 2 ($p < .005$). This is yet another way to document the DAY 3 stage 1 increase. However, this measure emphasizes that the stage 1 increment is not merely the result of one particularly long period of stage 1 sleep on DAY 3, but rather, the product of an increase in the number of relatively brief stage 1 episodes. This increase in transient light sleep epochs is associated with significantly more brief fluctuations to wakefulness (indexed by the appearance of EEG alpha) following both stage 1 sleep onset ($p < .01$) and the more rigorous stage 2 onset ($p < .025$) criterion. Examination of individual records indicated that the fluctuations to transient wakefulness tended to precede the stage 1 epochs, rather than the converse.

If, however, stage 1 increases were resulting from increased wakefulness, then overall there should have been significantly more wakefulness on DAY 3, and less TST. Yet this was clearly not the case. The fluctuations to transient wakefulness had to therefore be extremely short to not increase the proportion of wakefulness overall. Indeed, as Table 4 shows, when the number of awakenings of 45 seconds duration or longer are counted, there was no longer an effect of nap DAYS. Total number of stage fluctuations shows the same relationship as a function of epoch length. Stage lability is significantly higher on DAY 3 when 30-second stage changes are tabulated ($p < .05$), but when the minimum length criterion is extended to 1-minute stage changes, the effect vanishes.

It appears, therefore, that the loss of some stage 4 sleep and concomitant increase in stage 1 sleep during naps in the alerting

environment of DAY 3 is a direct consequence of increased stage lability -- specifically, very transient fluctuations from deeper sleep to wakefulness and light sleep. We sought to determine if a particular characteristic of the DAY 3 alerting environment might have produced the increased stage lability. Certainly the Ichihara et al. (1979) study would suggest the DAY 3 chair vs. the DAY 2 bed might have been sufficient to account for the results. However, the PBSS and data from studies on the effects of varying sound on nocturnal sleep (e.g., Cantrell, 1974; Thiessen, 1978) suggest that the extraneous sounds of DAY 3 also contributed to the changed nap sleep infrastructure.

While the study was not designed to specifically test the effect of any one environmental parameter on nap sleep, it was possible to determine the extent to which the DAY 3 extraneous sounds affected sleep, since these were recorded on the polygraph paper as they occurred. Though the noises were not particularly loud (40 dB to 62 dB spl), they were audible and fairly frequent, and sleep stage fluctuations did follow their occurrence. However, there was no significant pattern of stage lability associated exclusively with the extraneous sounds of DAY 3. This was the case for all three groups. Thus, it seems likely that the nap sleep infrastructure differences observed between DAYS 2 and 3 were produced by the combination of noise, light, and the chair.

Another possible interpretation of the nap day differences would be that they reflect adaptation to the laboratory, particularly to sleeping in the laboratory, and are therefore due to a first nap effect analogous

to the "first night effect" observed for repeated nocturnal sleep recordings in the laboratory. Agnew, Webb, and Williams (1966) describe adaptation effects (on nocturnal sleep) in the second and later laboratory periods as (1) less wakefulness and less stage 1 time, (2) an earlier onset of stage 4 sleep, and (3) fewer stage changes. Lawrence (1971) described similar effects for repeated laboratory naps. The effects we observed, however, were significant in the direction opposite of laboratory adaptation effects. We found more stage 1 sleep on DAY 3 (the second nap day) than DAY 2, and more stage changes on DAY 3. Since we deliberately designed the study so that laboratory adaptation effects would work against the experimental hypotheses, these findings are especially compelling.

Finally, it is relevant to note that though the DAY 3 nap period onset time (3:50 p.m.) was significantly earlier than the DAY 2 nap period onset time (4:20 p.m.) ($F_{1,20} = 6.85, p < .025$), the difference averaged only 30 minutes,* which is not nearly enough time to account for DAYS effects by suggesting circadian variations in sleep stage proportions. Similarly, the amount of prior wakefulness before the laboratory naps was not significantly different within or between groups across DAYS 2 and 3.

*DAY 3 was scheduled to begin at the same time as DAY 2 to prevent circadian factors from influencing nap sleep; however, because the pre-nap procedures of DAY 3 were shorter than DAY 2, a 30-minute significant difference in time of nap period onset between the two days occurred.

c. Other physiological results.

(1) EEG alpha activity. In our earlier study (Evans & Orne, 1975) we noted that non-nappers had less EEG alpha activity (8-12 Hz) than nappers during the 5-minute waking baselines immediately prior to and 15 minutes following a nap in a sleep-conducive environment. Since we recorded alpha percentage and frequency during waking baselines before and after nap DAYS 2 and 3 of the current study, we were able to compare groups again, as well as the effect of nap DAYS.

Nappers and non-nappers did not differ significantly in the current study in either alpha percentage (group means ranged from 40% to 60%) or frequency (9.5 Hz to 10.5 Hz). Immediately prior to the DAY 2 nap, all groups (those subjects who slept on DAYS 2 and 3) had significantly less alpha percentage than immediately after the DAY 2 nap ($F_{1,22}=15.31$, $p<.001$), and less alpha than immediately before their DAY 3 nap ($F_{1,20}=9.35$, $p<.01$). Alpha percentage increased from before the DAY 3 nap to after the DAY 3 nap ($F_{1,22}=4.58$, $p<.05$), but the change was less robust than on DAY 2.

The lower alpha percentage prior to the nap periods of DAYS 2 and 3, particularly prior to DAY 2, was likely the result of increased drowsiness prior to the nap (see Paskewitz & Orne, 1972). Nevertheless, since the DAY 2 alpha baselines were taken while the subject was lying in the bed, in the dark, quiet room, it is not surprising that the DAY 2 pre-nap baseline had the least alpha, since it was probably the period of greatest drowsiness for all subjects, especially those who subsequently slept.

While it might be tempting to conclude that the naps served to increase the percentage of alpha in the wake EEG, the greater drowsiness before the naps compared to after is a more parsimonious explanation for alpha increases across the naps. This is supported by the fact that the 4 non-nappers who did not fall asleep on DAY 2 also averaged significantly less alpha before the nap period than after the nap period ($t=2.62$, $p<.05$). Clearly, it could not have been sleep per se that increased their alpha percentage.

Unlike alpha percentage, alpha frequency did not change significantly from pre-nap to post-nap for subjects who slept on either nap DAY 2 or 3. However, all groups did have significantly lower alpha frequency on DAY 3 relative to DAY 2 pre-nap ($F_{1,20}=10.52$, $p<.005$) and post-nap ($F_{1,20}=10.51$, $p<.005$) baseline.* Though subjects who slept had no significant change in alpha frequency across the naps, non-nappers who did not sleep on DAY 2 had a significant drop in alpha frequency from pre- to post-nap period on DAY 2 ($t=4.97$, $p<.02$, two-tailed).

If increased EEG frequency following naps is assumed to be indicative of increased physiological activation, as Taub (1977) and others have suggested, then non-nappers who were unable to sleep on Day 2 were significantly less activated by EEG criteria after the DAY 2 nap period relative to before it. Similarly, subjects were generally less activated by

*Wilcoxon matched-pairs signed-ranks tests confirmed these DAY 2 versus DAY 3 EEG frequency differences, though the effect appeared less robust nonparametrically ($p<.18$ for pre-nap frequency, and $p<.01$ for post-nap frequency, two-tailed).

EEG criteria on DAY 3 relative to DAY 2.

The lack of changes in alpha frequency from pre-nap to post-nap baselines on DAYS 2 and 3 were unexpected, since Taub (1977) reported that EEG frequency increased significantly for habitual nappers from 20 minutes before to 20 minutes after 1/2-hour and 2-hour afternoon laboratory naps. These cortical frequency increments were part of a pattern of psychophysiological changes that he interpreted as increased activation resulting from naps. Heart rate, electrodermal activity, and subjective activation also showed significant increases across the naps, and all measures were intercorrelated with improved RT performance following naps, relative to wake control periods. EEG frequency change correlated highest with RT improvements.

It is possible that methodological differences between our study and Taub's (1977) precluded our finding the EEG frequency results that Taub observed. Since he also noted significant changes in heart rate across naps, and since we recorded heart rate during our nap periods, we sought to confirm his observation on that parameter. It also seemed worthwhile to assess whether DAY 3 was associated with higher heart rates, analogous to the higher EEG frequencies of that DAY.

(2) Heart rate and electrodermal activity. Heart rate was measured frequently throughout nap periods on DAYS 2 and 3, as well as during the middle of the 5-minute waking baselines recorded immediately before each nap and 15 to 20 minutes after each nap. When heart rate during the pre-nap and post-nap baselines was compared within each nap day, no group

effects, nap effects, or nap DAY effects were found. Contrary to Taub's (1977) report, there was no significant increase from pre-nap to post-nap waking baseline for specific groups or all subjects combined. Moreover, unlike alpha frequency, there was no significant difference between the heart rates of nap DAYS 2 and 3.

Electrodermal data were not as thoroughly scored as the other physiological parameters, due to the generally lower priority of this parameter compared to the nap sleep characteristics. Nevertheless, analyses of skin resistance levels during the pre-nap and post-nap baselines of DAYS 2 and 3 revealed no significant differences within or between DAYS or groups.

Although we were unable to replicate either Taub's (1977) physiological findings or our earlier EEG frequency results for nap DAYS, the heart rate and electrodermal data are in agreement in lack of effects, and generally fit with the alpha frequency findings in terms of no clear changes occurring from before to after the naps. Of course this does not mean that subjects did not derive significant subjective benefits from the naps, or that physiological parameters had no relationship to performance and subjective ratings in our study. As will be detailed later, performance after the naps was meaningfully related to physiological aspects of nap sleep, and physiological parameters appeared to roughly indicate which individuals would be able to nap.

(3) Oral temperature. Body temperature appeared to be related to napper - non-napper differences in our earlier work, such that replacement nappers had somewhat lower temperatures than non-nappers, prior to a laboratory nap. For the current study we recorded sublingual temperature several times, both

before and after naps and on control days, to determine to what extent temperature was related to group differences and nap effects, relative to wake control periods.

Our hypothesis regarding group differences predicted that non-nappers would have significantly higher temperatures than nappers prior to laboratory naps (Evans & Orne, 1975) but not necessarily after naps, since body temperature tends to drop during sleep and during some periods of quiet wakefulness (Kleitman, 1963). Indeed, temperature changes from 5 minutes before to 5 minutes after both nap DAYS 2 and 3, as well as control DAYS 1 and 4, dropped significantly for all groups (trials' F s were significant on each of the 4 days at the $p < .025$ level and lower). Approximately 45 minutes after the nap days, each group's mean temperatures returned to near their pre-nap values.

Examination of pre-nap temperatures for groups revealed that non-nappers averaged higher temperatures than nappers, and in particular, the 4 non-nappers who did not sleep on DAY 2 averaged the highest temperatures, at least on that day. Replacement and appetitive napper groups did not differ from each other, however, in mean pre-nap temperatures, and consequently were pooled for comparison with non-nappers. Figure 4 illustrates mean body temperatures for all 9 non-nappers and 21 nappers* at 60 minutes prior to and again at

*One appetitive napper had to be excluded from this analysis due to missing temperature data on DAY 3. All subjects were included in these analyses, regardless of whether they slept during the nap periods, since the comparisons were on temperatures prior to the naps. The temperatures presented in Figures 4 and 5 may appear to be a few tenths of a degree lower than typical clinical recordings. This is a function of the Tempa-Dot thermometers employed both in the laboratory as well as at home for circadian data. Given the number of subjects, and the extent of the data collected, it was considerably more practical to use these disposable thermometers than alternative glass bulb thermometers. Our pilot data indicated the Tempa-Dots would be sensitive to diurnal fluctuations in temperature, and the laboratory data as well as the circadian data we collected during the study confirm that impression.

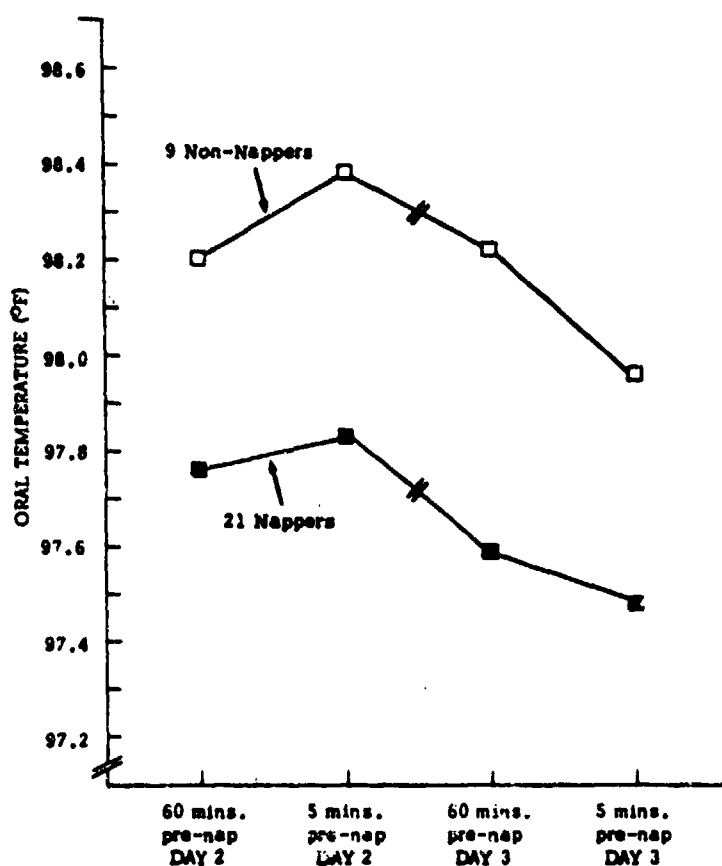


Figure 4. Mean sublingual temperature readings taken during the 1-hour period prior to the laboratory naps. Confirmed non-nappers were compared to a combined replacement and appetitive napper group. Two-way repeated measures analysis of variance on the data yielded a main effect for groups ($F_{1,28}=6.08, p<.025$), and a main effect for trials ($F_{3,84}=26.13, p<.001$), but no interaction ($F_{3,84}=0.93, p>.20$).

5 minutes prior to the DAY 2 and DAY 3 nap periods. The two-way repeated measures ANOVA yielded a significant between-groups effect ($F_{1,28}=6.08, p<.025$), and *t*-tests for a priori comparisons between nappers and non-nappers at each point confirmed that nappers averaged significantly ($p<.001$, two-tailed) lower body temperatures than non-nappers before both laboratory naps.

If the higher body temperatures of non-nappers were indicative of a tonic level of higher arousal relative to nappers, then non-nappers should

also have significantly higher body temperatures upon coming to the laboratory on control DAYS 1 and 4. However, this was not the case. While nappers continued to average lower temperatures on control days compared to non-nappers, the differences were considerably less than the pre-nap days' differences, and there was no overall main effect between groups ($F_{1,28}=1.15$, $p>.20$).

The differences pictured in Figure 4 appeared, therefore, to be representative of subjects' state prior to the sleep sessions on laboratory nap days, but not necessarily reflective of non-nap control days. It appears that nappers reacted to the nap and control days differently, such that they were physiologically prepared to nap upon coming to the laboratory DAYS 2 and 3 (and their body temperatures reflected this lower arousal), while they were aware they would not be napping on control DAYS 1 and 4 (and thus were generally more activated). This view predicts that nappers should average significantly lower body temperatures on laboratory nap days (prior to the nap periods) compared to wake control days, while non-nappers should have no significant difference between nap and control day temperatures. To test this, we compared the first temperature recording taken on the two nap days to the first temperature recording taken on the two control days.

Figure 5 presents the results of these comparisons within each group. As predicted, the main effect for days (nap days versus control days) was significant for replacement nappers ($F_{1,30}=20.96$, $p<.001$) and appetitive nappers ($F_{1,27}=4.73$, $p<.05$), but not for non-nappers

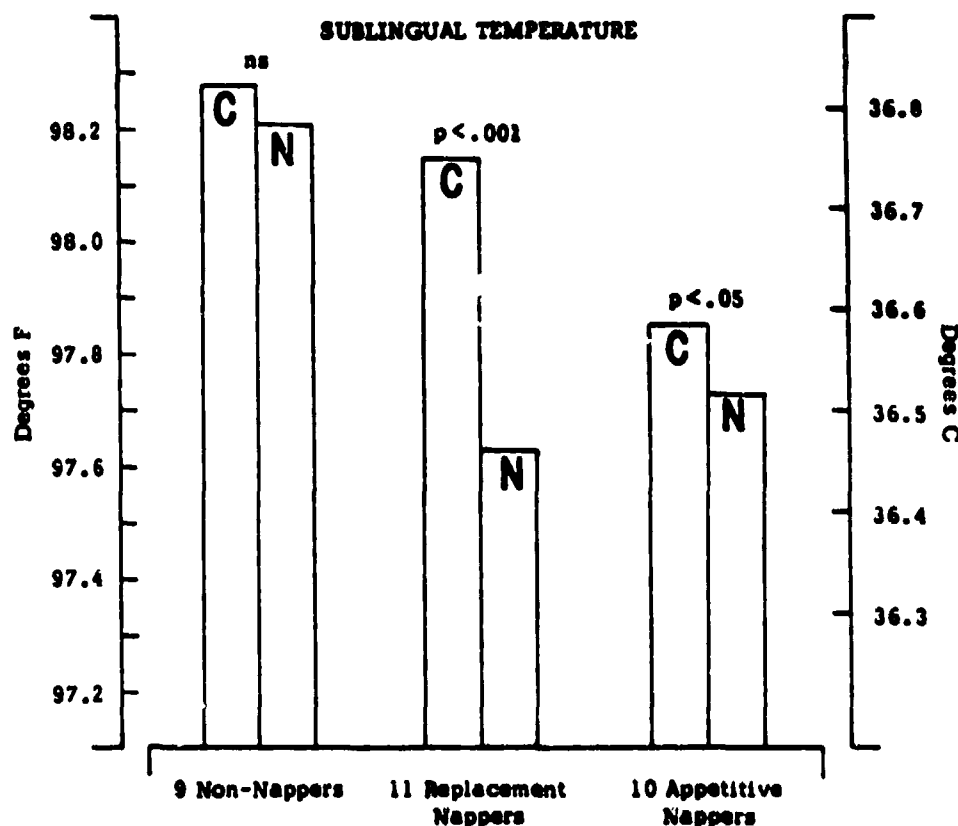


Figure 5. Histograms of mean sublingual temperature for the first recording made on (C) wake control days (DAYS 1 & 4), and (N) laboratory nap days (DAYS 2 & 3). In all cases the recordings were made about 1 hour prior to the 60-minute wake or nap periods. Treatment by treatment by subjects analysis of variance was performed within each group.

($F_{1,24}=1.60$, $p>.20$). Nappers averaged significantly lower body temperatures before the nap periods than before the wake control periods. The effect was larger for replacement nappers, but when the second temperature reading (5 minutes pre-nap or pre-control period) was used, the effect was greater for appetitive nappers ($F_{1,27}=12.46$, $p<.005$) than replacement nappers ($F_{1,30}=7.27$, $p<.025$). Of course, combined napper groups also showed the effect. The data suggest that nappers have lower physiological arousal, as indexed by body temperature, prior to anticipated nap periods.

It is noteworthy that Taub (1977) reported oral temperature increased in his subjects from 20 minutes before to 20 minutes after a wake control period but not laboratory naps, while heart rate, EEG frequency, electrodermal activity, subjective activation, and behavioral efficacy (RT) showed significant increases following naps but not following a wake control period. This led him to suggest that the assumption that temperature is a comprehensive index of organismic activation may be invalid if one is talking about activation as a unitary concept in psychophysiological terms.

Indeed, there are frequent conditions where temperature and other physiological and subjective parameters are out of synchrony, and thus a unitary concept of activation is probably inappropriate. We have found, however, that the assessment of body temperature surrounding naps and wake control periods requires frequent measurement to appreciate the various parameters that can affect this variable. Thus, depending on when temperature is taken following a nap or control period, whether an individual is a napper or non-napper, and what a subject does between the period and the measurement will determine whether one sees significant increases or decreases in temperature, regardless of whether sleep has occurred.

Furthermore, sublingual temperature may reflect not only arousal manipulations the experimenter imposes intentionally, but also arousing aspects of the setting not of obvious relevance to the study. For example, our temperature data showed a significant drop across laboratory visits for all groups individually and pooled, including those subjects who napped on both DAYS 2 and 3 ($F_{3,60}=25.09$, $p < .001$). This is apparently a

laboratory adaptation curve that exists largely independent of the temperature changes between groups, across 60-minute treatments, and within napper groups between control and nap days. Body temperature therefore appears to vary systematically as a function of a number of parameters, and its assessment requires attention to these parameters, as well as circadian and environmental influences.

A careful timing of temperature recording can, nevertheless, provide some insight into individual differences in the ability to sleep, or to sleep and derive benefits from it. Just as Monroe (1967) found that poor nocturnal sleepers had significantly higher body temperatures prior to and during their nocturnal sleep relative to good nocturnal sleepers, we found that poor daytime sleepers (confirmed non-nappers) had significantly higher body temperatures prior to naps relative to good daytime sleepers (nappers). While we believe that the higher temperatures roughly index non-nappers' inability to onset sleep in the afternoon, at least in the laboratory, we are less certain that the temperatures relate meaningfully to the unpleasant post-nap aftereffects confirmed non-nappers report experiencing. Performance data, subjective data, circadian data, and sleep diary data must be assessed before concluding that the sleep staging, stage lability, and temperature differences we observed are relevant to nappers' use of napping to enhance effective functioning, and confirmed non-nappers' avoidance of napping.

2. Performance Results.

a. Sleep infrastructure and post-nap performance. DST and RNG performance were assessed throughout experimental and control sessions,

including immediately after nap period termination on DAYS 2 and 3, as well as 35 minutes later. RT performance was recorded at nap offset (subjects were required to answer a phone signaling the nap period was over) and again 20 minutes later.

While both DST and RT post-nap performance appeared to be affected by nap sleep, RNG performance was not affected by either nap sleep or wake (control) periods, and groups did not differ in their degree of randomness at any point. DST and RT, on the other hand, were profoundly influenced by the nap periods relative to wake periods. Specifically, performance on both tasks was depressed within a few minutes of nap termination, but recovered within 20 to 35 minutes. Since qualified nappers and non-nappers did not differ in their baseline performance on DST and RT tasks, it seemed reasonable to first examine the relationships between post-nap performance and nap sleep infrastructure, and then compare specific groups. Consequently, we initially analyzed the performance of all 67 subjects seen in the laboratory, including unconfirmed nappers and non-nappers.

Figures 6a and 6b graphically present DST and RT performance prior to and following nap DAYS 2 and 3, respectively, for all 67 subjects. Immediate post-nap performance decrements and subsequent increments are evident for RT and three measures of DST performance, including both speed and accuracy. On nap days, RT to the phone was significantly slower at nap termination than 20 minutes later ($t=3.56$, $p<.001$; and $t=2.32$, $p<.05$, two-tailed). Similarly, DST performance parameters were

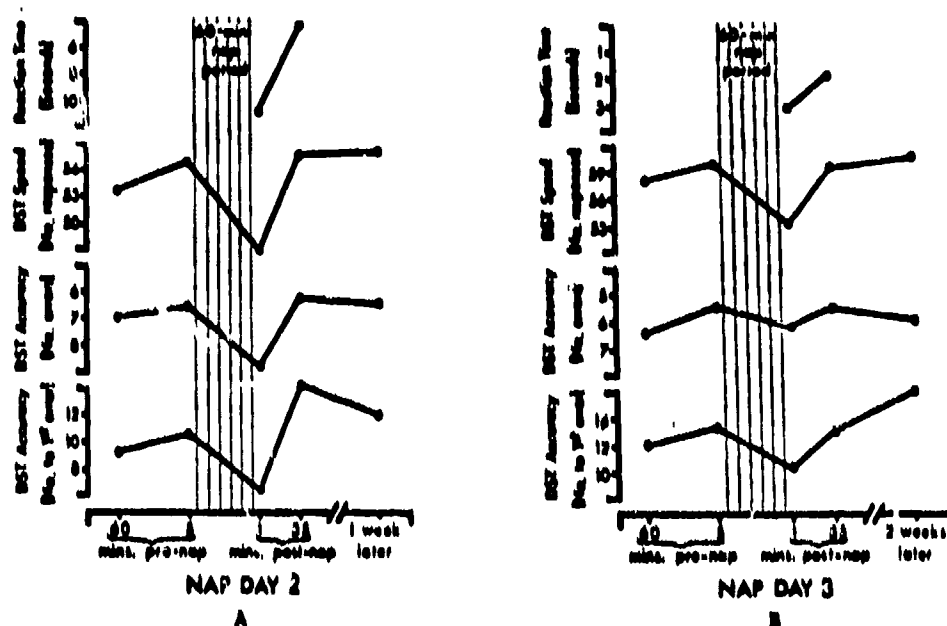


Figure 6. Mean performance on reaction time (RT) and three measures of descending subtraction task (DST) for 67 young adults before and after naps in a sleep-conductive environment (A) and in an alerting environment (B). Better performance is up on all graphs. Performance at 1 minute post-nap was significantly below pre-nap and subsequent post-nap levels for all measures except DST accuracy on DAY 3.

significantly poorer immediately after the naps compared to before the nap periods, 35 minutes later, and wake control periods (all t s significant at $p < .05$ or lower, except for DAY 3 accuracy measures where t s were $p < .20$, two-tailed). Overall, therefore, it appeared that both simple motor reaction time and complex cognitive performance were depressed upon awakening, and then improved shortly thereafter. Wilcoxon matched-pairs signed-ranks tests confirmed these findings.

The robustness of these immediate post-nap performance decrements, as well as their relevance to the implementation of napping regimes during quasi-continuous performance schedules, encouraged a complete assessment

of the decrements in relation to nap sleep infrastructure. The DST measure we employed for these analyses was the number of correct responses per second, times 1000. This measure was sensitive to both speed and accuracy changes. RT was carried as the speed of response in seconds. A variety of dimensions of nap sleep infrastructure were correlated with RT and DST performance changes across the nap periods.

(1) RT decrement. Table 5 presents the resulting Pearson product moment correlation coefficients with an adjustment of significance

TABLE 5

Product moment correlations between immediate post-nap performance and nap sleep of 67 young adults.

Task	Nap Day	DST	Sleep Stages					Awake*	Stage*
			1-4	2-4	3-4	2	1		
RT		.00	.15	.13	.14	-.05	-.08	-.17	.42*
		-.17	.12	.09	.18	-.07	-.02	-.09	.37*
DST			-.45*	-.40*	-.38*	-.35	.03	.25	-.14
			-.52*	-.60*	-.58*	-.23	.08	.35	-.43*

* Time awake or in Stage 1 immediately prior to bell.

Stage at bell.

* $p < .002$ for $p < .05$ by two-tailed Bonferroni procedure.

levels using a multistage Bonferroni procedure (Larzelere & Mulaik, 1977) to minimize the possibility of capitalizing on chance given 30 correlations on a data set.* Examination of Table 5 shows that RT and DST post-nap performance decrements were not correlated on either nap day, suggesting they were associated with different aspects of nap sleep.

RT was significantly correlated with only one parameter, namely,

 *All significant effects regarding post-nap performance were also confirmed using Spearman rank order correlations and chi square analyses.

stage at the bell (nap termination), such that the deeper the sleep stage (awake=0, stage 1=1, ... stage 4=4) the slower the RT. Figure 7a illustrates

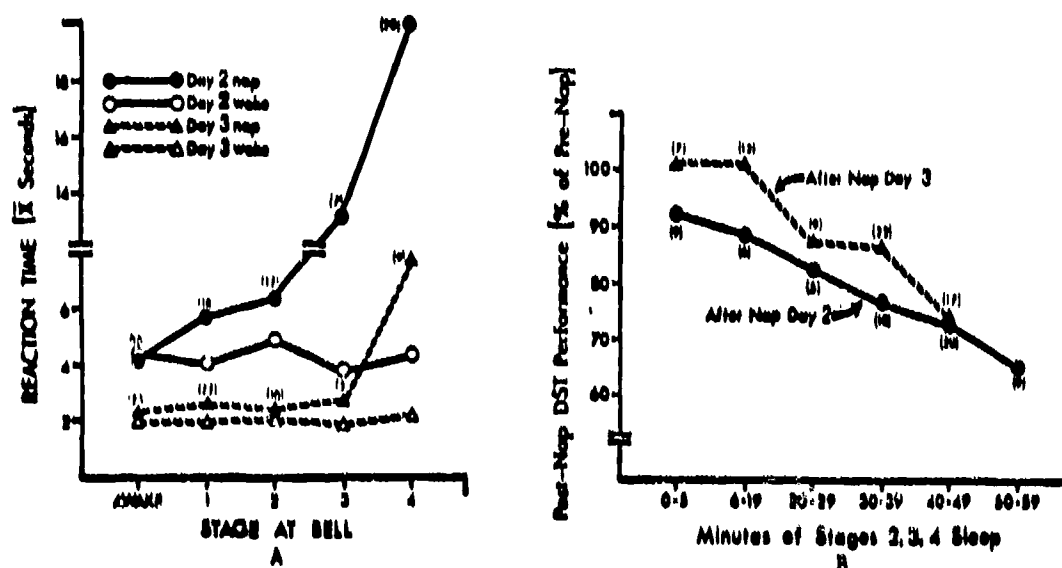


Figure 7. (A) Mean reaction times to answering a telephone for young adults in various stages of sleep at the termination of 60-minute afternoon nap periods in sleep-conductive (DAY 2) and alerting environments (DAY 3). Values in parentheses are the number of subjects included in each data point on each nap day. The wake condition was the mean RT for subject groups 20 minutes after naps. The DAY 2 RTs were to a 72-dB bell whereas DAY 3 RTs were to a 93-dB bell. (B) Immediate post-nap DST performance as percent of pre-nap levels for subjects varying in amount of stages 2+3+4 sleep during nap DAYS 2 and 3. The DST measure employed was the number correct per unit time, and thus includes adjustment for speed and accuracy. Values in parentheses are the number of subjects at each data point. No subject had more than 50 minutes stages 2+3+4 on DAY 3.

this relationship. While the louder DAY 3 bell and alerting environment served to decrease RT from all stages relative to DAY 2 ($p < .0001$), the bulk of the RT decrement at nap termination resulted from stage 4 sleep awakenings.* This confirms findings from nocturnal studies of sudden

*Two-way repeated measures ANOVA within each nap day (Figure 7a) yielded a main effect between groups (i.e., stages: DAY 2 $F_{4,62}=3.43$, $p < .025$; DAY 3 $F_{4,62}=3.43$, $p < .025$), a main effect within groups (i.e., nap vs. wake RT: DAY 2 $F_{1,62}=15.13$, $p < .001$; DAY 3 $F_{1,62}=6.23$, $p < .001$), and a significant interaction (DAY 2 $F_{4,62}=4.18$, $p < .005$; DAY 3 $F_{4,62}=4.54$, $p < .01$). Post hoc Scheffé comparisons between means within each nap day revealed that RT from stage 4 sleep was significantly longer ($p < .01$) than RT from all other stages.

awakening (Goodenough et al., 1965; Okuma et al., 1966; Scott & Snyder, 1968) and Webb and Agnew's (1964) study of afternoon naps. Immediate post-nap RT performance is related to stage of sleep at awakening, and not to time spent in sleep or any other cumulative factor.

(2) DST decrement. The converse appeared to be true for DST immediate post-nap performance decrement. As Table 5 shows, DST performance was significantly related to the amount of sleep on nap DAYS 2 and 3, but not necessarily to stage at awakening. In fact, the highest DST coefficients within each nap day were for the relationship with stages 2+3+4 sleep combined, that is, TST from stage 2 onset ($r = -.48$, $p < .0001$, and $r = -.60$, $p < .0001$). The more the TST during naps, the poorer the immediate post-nap cognitive performance. Figure 7b depicts this relationship on each nap day.

Chi square analysis between nap days confirmed that a day of greater stages 2+3+4 sleep for a subject was likely to be a day of greater DST decrement ($\chi^2 = 11.66$, $df=1$, $p < .001$). This was not the case, however, for the relationship between stage at nap termination and DST decrement ($\chi^2 = 0.44$). Even subjects who were awake or in stage 1 sleep at nap termination had a DST decrement proportionate to their TST as long as they had not been awake (or in stage 1) more than 5 minutes. If they had been awake for more than 5 minutes, their DST decrement was less than usual for a given sleep length, indicating the DST performance begins rebounding back to pre-nap levels within 5 to 10 minutes of nap termination. By roughly 35 minutes after the nap, DST performance had

rebounded to or above pre-nap levels, such that the greater the decrement, the greater the subsequent increment to pre-nap levels.

These results dramatize a number of issues relevant to napping in a context where an individual may be required to perform at peak efficiency, at a moment's notice, and at unpredictable times. First of all, the alerting environment of DAY 3 had much less effect on post-nap performance decrements than we had anticipated. Both motor and cognitive deficits were evident on DAY 2 as well as DAY 3. Moreover, the degree of the cognitive performance decrement was remarkably similar to that found after awakening from nighttime sleep (19%-25%; cf. Pritchett, 1964; Hartman & Langdon, 1965; Wilkinson & Stretton, 1971).

Furthermore, the common assumption that performance at awakening is the result of the carry-over effects of the brain's state immediately preceding awakening was not supported for cognitive performance. While simple motor RT reflected the expected sleep stage effect, DST performance (both speed and accuracy) was unrelated to sleep stage at nap's end, but was related to total sleep time.* While we did not predict this, the finding is congruent with a growing body of evidence suggesting that sleep length is considerably more powerful in predicting certain aspects of performance

*DST decrement was significantly correlated with stage at nap termination on DAY 3, but not on DAY 2 (see Table 5). However, the correlation was less robust than the TST-DST coefficients, and partial correlations revealed that the DST correlation to stage at nap termination on DAY 3 was the result of TST being significantly correlated with stage at nap termination on that day ($r = .48$, $p < .0001$). When TST was partialled out, stage no longer correlated significantly with DST decrement on DAY 3 ($r = .19$, $p > .10$), and when stage at nap termination was partialled out, TST still correlated significantly with DST decrement ($r = .50$, $p < .0001$).

after sleep than any particular sleep stage (Johnson, 1973; Johnson, Naitoh, Moses, & Lubin, 1974; Lubin, Moses, Johnson, & Naitoh, 1974).

While TST was clearly associated with DST decrement on nap days, there was, nevertheless, some indication that it was amount of stages 3+4 sleep that contributed most to this relationship. All the significant correlations in Table 5 between DST and sleep length involve slow-wave sleep, and the correlations between DST and stage 2 sleep, or stage 1 sleep alone (as well as stages 1+2 sleep combined) were not significant. Thus, it is possible that given the same total sleep time, but differing amounts of stages 3+4 sleep, the subject with the greater slow-wave sleep would likely experience the greater DST decrement. In light of this, we examined our nappers' and non-nappers' performances and their relationships to the nap sleep infrastructure differences we observed.

b. DST performance of nappers and non-nappers. Having found such robust relationships between immediate post-nap performance and sleep infrastructure for all 67 subjects, we expected that differences in post-nap performance between our 11 appetitive nappers, 11 replacement nappers, and 9 non-nappers would be a function of nap sleep infrastructure differences. Since groups did not differ significantly in stage at nap termination on either DAY 2 or 3 ($F_{2,20}=1.13$, $p>.20$), it is not surprising that RT was not significantly different between groups on either nap day ($F_{2,20}=0.48$, $p>.20$).

Furthermore, since groups did not differ in TST ($F_{2,20}=0.12$, $p>.20$),

DST decrements were not different ($F_{2,20}=1.12$, $p>.20$). Nevertheless, an examination of DST speed and accuracy revealed that confirmed non-nappers who slept had significantly more DST errors (lower accuracy) immediately after the DAY 2 nap relative to both replacement nappers ($t=2.44$, $p<.05$, two-tailed) and appetitive nappers ($t=1.93$, $p<.10$, two-tailed) who slept, as well as non-nappers who did not sleep ($t=3.75$, $p<.01$). These differences were not evident on nap DAY 3 or any wake control day.

Interestingly, the one nap infrastructure parameter that non-nappers experienced more of on DAY 2 relative to both napper groups was amount of stages 3+4 sleep (N vs. R, $t=3.61$, $p<.01$; N vs. A, $t=2.59$, $p<.05$, two-tailed). Replacement and appetitive nappers did not differ in either slow-wave sleep or DST post-nap accuracy decrements. In addition, non-nappers averaged significantly less stages 3+4 sleep on DAY 3 relative to DAY 2 ($t=4.49$, $p<.02$, two-tailed) and, not surprisingly, fewer DST errors on DAY 3 ($t=7.90$, $p<.002$, two-tailed).

Figure 8 illustrates these data by presenting percent of slow-wave sleep and DST errors immediately after nap DAYS 2 and 3 for each group. It seems clear that the increased number of errors non-nappers made on DAY 2 were directly associated with their increased amount of deep sleep on that day, despite the fact that overall they had the same TST (from stage 2 onset) as nappers and averaged the same sleep stage at nap termination. Furthermore, when the amount of their deep sleep was reduced on DAY 3 relative to DAY 2, their DST accuracy increased after the DAY 3

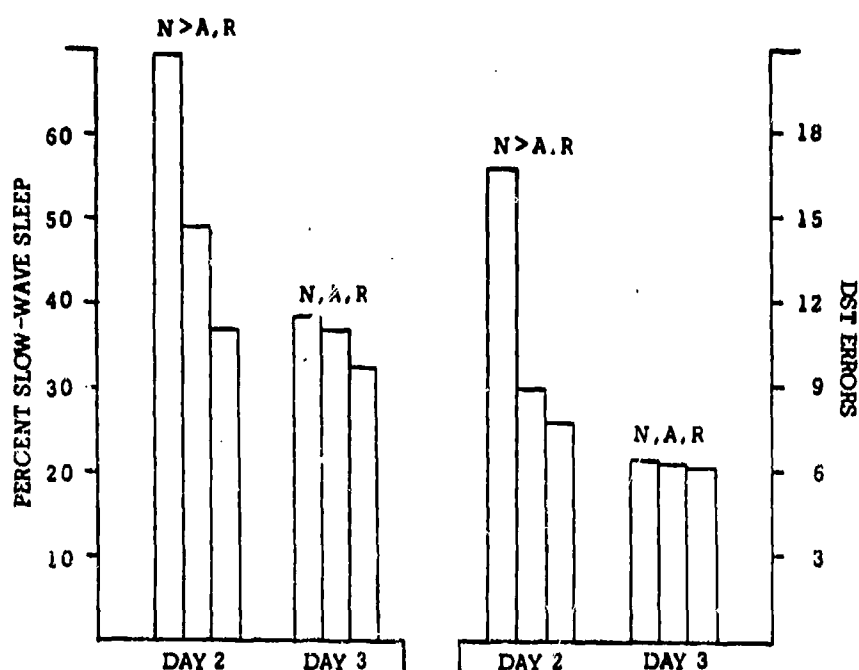


Figure 8. Mean percent of stages 3+4 sleep and mean number of DST errors immediately after nap termination for 5 non-nappers (N), 9 appetitive nappers (A), and 9 replacement nappers (R) who slept on both DAYS 2 and 3. On DAY 2, non-nappers had a significantly greater proportion of slow-wave sleep during their naps compared to appetitive nappers ($p < .05$) and replacement nappers ($p < .01$), and following their DAY 2 naps they had more DST errors than appetitive ($p < .10$) and replacement ($p < .05$) nappers. All tests were two-tailed. Napper groups did not differ significantly from each other on DAY 2, and no group differences were evident on DAY 3. Non-nappers had a smaller proportion of stages 3+4 sleep ($p < .02$), and fewer DST errors ($p < .002$) on DAY 3 relative to DAY 2.

nap relative to DAY 2. Finally, even though napper groups did not differ significantly in amount of deep sleep and DST accuracy, appetitive nappers averaged somewhat more of both on DAY 2 compared to replacement nappers, and thus the napper groups' ranks on stages 3+4 sleep on DAY 2 match their DST accuracy ranks.

This finding raises the intriguing possibility that it is the inordinately higher proportion of deep sleep, and subsequent greater immediate post-nap cognitive decrement that confirmed non-nappers experience as "unpleasant"

or a "negative aftereffect" which leads them to avoid napping. While our earliest experimental hypothesis regarding non-nappers' avoidance of napping was predicated upon the assumption that they had excessive amounts of deep sleep during naps, and though the DAY 2 data confirm this, the DAY 3 data and our earlier study do not entirely support this view.

In our earlier study on napping in an optimal environment (Evans & Orne, 1975), a delayed sleep onset probably resulted in confirmed non-nappers having no more slow-wave sleep during their naps than nappers (see Table 2); and on DAY 3 of the current investigation the alerting environment apparently reduced their deep sleep to the level of nappers' (see Table 3). Thus, on DAY 3 non-nappers had no greater immediate DST post-nap decrement than nappers. Can we predict, therefore, that they were less dissatisfied with the DAY 3 nap compared to the DAY 2 nap? Although the post-nap DST and deep sleep data would suggest a positive answer to this question, examination of subjective data reviewed below does not support such an answer.

Though the post-nap performance decrement provides important information on the relationship of nap sleep infrastructure to performance, it is relevant to remember that all subjects evidenced a return of both RT and DST performance to or above pre-nap levels within 35 minutes of nap termination. Since RT was recorded only after naps, it was not possible to compare it to RT before naps and RT on wake control days, to determine if we could replicate Taub's (1977) finding of increased RT performance following naps by habitual nappers. In this regard, it is noteworthy

that Bertelson (1979) was not able to replicate Taub's RT findings, and thus some doubt remains concerning the degree to which simple motor efficiency improves following naps in non-sleep-deprived subjects.

Like Taub (1977) and Bertelson (1979) we did not find that performance on a complex cognitive task improves significantly above pre-nap levels in non-sleep-deprived nappers and non-nappers. Of course, this may be a function of not having tested cognitive performance frequently enough following naps. Nevertheless, our data show that, regardless of the degree of immediate post-nap cognitive performance impairment, the rebound during the subsequent 30 minutes is proportionate to the decrement. Moreover, this is true for both nappers and confirmed non-nappers. Thus, non-nappers do not appear to be suffering any prolonged cognitive deficits as a result of having napped. This is not to say, however, that the subjective consequences of a nap are similar between these groups.

3. Subjective Results.

Extensive subjective data was collected throughout the study, and included repeated measures of reported sleep depth, time estimates, activation, sleepiness, fatigue, nap satisfaction, tiredness, capacity, and refreshedness. While we realize that some of these measures are inherently intercorrelated,* we have found it desirable to permit subjects the broadest

*Correlational analyses were carried out within and between the 10 subjective measures employed in the study. By correlating all 31 subjects' responses to each subjective measure at the same time point within a given day, it was possible to determine what the average Pearson correlation was between any two measures. When all 10 measures were intercorrelated with each other, a clear pattern emerged. Not all 10 subjective scales were measuring the same parameter. Rather, subsets of measures were intercorrelated, yielding 4 separate domains. Post-nap ratings of satisfaction, "feeling now," and refreshedness

range of ratings, since, for example, ratings of sleepiness and refreshedness often mean different things to subjects. The measures employed reflect those hypothesized to show group or nap effects, as well as those reported in the literature to be relevant to assessing the subjective effects of naps. By comparing post-nap ratings to pre-nap ratings and wake control day ratings, within and between groups, the effects of naps on nappers and non-nappers can be evaluated, taking into account non-sleep-related changes over time.

a. Post-nap ratings of depth, time, satisfaction, and aspects of fatigue.

(1) Replication of effects from an optimal environment. Our earlier work had shown that following naps in a sleep-conducive environment, nappers (especially appetitive nappers) were more satisfied with their naps than confirmed non-nappers, and felt better following a nap relative to before it (Evans & Orne, 1975). Table 6** presents these results for the earlier study,

 were all highly correlated (.69 to .76), but were generally uncorrelated with other measures. The largest single matrix of intercorrelations was comprised of ratings of fatigue, sleepiness, tiredness, and AD-ACL factors, general activation and deactivation-sleep, all of which were significantly intercorrelated (.31 to .72). AD-ACL factors of high activation and general deactivation made up the final two domains. Neither was correlated with any other subjective measure, and they were only weakly related (inversely) to each other (-.34). In addition to the relationship between measures, the reliability of each measure was assessed by checking the intercorrelation between repeated administrations of each scale. All scales showed satisfactory reliability within any given day (r_s ranged from .41, $p < .05$ to .89, $p < .0001$). Each scale's reliability dropped when assessed between days of the study, but 9 of the 10 subjective measures remained reliable (r_s ranged from .30, $p < .05$ to .58, $p < .001$). Only the high activation factor of the AD-ACL had a non-significant between-days reliability coefficient (.24), which is consistent with reports of increased variability in repeated measures on this factor (Thayer, 1967).

**Table 6 includes only those post-nap ratings that were made in the earlier study. Additional ratings employed in the current study are presented in later tables.

TABLE 6

Mean values of subjective responses for two studies of appetitive nappers (A), replacement nappers (R), and confirmed non-nappers (N) who slept during 60-minute afternoon nap periods in sleep-conductive environments.

Question	n =	Earlier study				DAY 2 of current study				difference replicated
		A 11	R 9	N 9	t-test results ¹	A 10	R 10	N 5	t-test results ¹	
How long since spoken to? ²		57	49	56		53	57	66		
How long did you sleep? ³		40	30	39		48	45	45		
Percent of time asleep?		56%	57%	47%		68%	70%	56%		
Awake at the bell? ⁴		0.9	0.8	0.8		0.9	0.5	0.8		
How deep at bell? ⁵		5.8	5.9	6.9		6.0	7.4	6.8		
How deep at deepest? ⁵		7.8	7.4	7.9		7.5	8.0	7.4		
#1 Nap satisfaction? ⁶		2.6	2.5	0.8	A,R>N	2.4	1.5	-0.4	A>N	A > N
#2 Nap satisfaction? ⁷		3.1	2.5	1.3	A,R>N	2.1	1.6	-0.6	A,R>N	A,R > N
#1 How do you feel now? ⁶		2.5	1.7	0.4	A>N	1.2	1.1	-1.2	A,R>N	A > N
#2 How do you feel now? ⁷		3.1	1.6	1.2	A>R,N	1.8	1.9	-0.8	A,R>N	A > N

¹ Differences significant at $p < .10$ (2-tailed) or less are reported.

² Asked at nap termination, subjects responded to a question regarding the time since they were told they could go to sleep (minutes).

³ Asked 5 minutes after the nap termination (minutes).

⁴ Answers scored as Yes = 2, not sure = 1, and No = 0.

⁵ Depth was rated on a 1 to 10 scale where 10 was as deeply as ever slept, and 1 was not even drowsy.

⁶ Rated within 10 minutes of nap termination, on a scale from -5 (very negative) through 0 (neither negative nor positive) to +5 (very positive).

⁷ Rated within 40 and 60 minutes of nap termination.

and for the replication by DAY 2 of the current study. While in both studies groups did not differ significantly in either post-nap estimates of sleep depth or time estimates, * the predicted differences in post-nap satisfaction and how subjects felt relative to before the nap were significant. The column on the far right in Table 6 displays the replicated differences.

Appetitive nappers were more satisfied with their nap in a sleep-conductive environment both immediately after the nap (6-10 mins. post-nap)

*There was some indication from our earlier work that nappers and non-nappers differed in their estimates of nap length, when their estimates were compared to actual sleep lengths from stage 1 or stage 2 sleep onset. These same comparisons were completed on the present study's data (both DAYS 2 and 3), and the earlier results were not replicated.

($p < .01$), as well as 40-60 mins. later ($p < .02$), compared to non-nappers. In general, replacement nappers were also more satisfied and felt better relative to non-nappers ($p < .10$ and $p < .05$), though the magnitude of their ratings was smaller than appetitive nappers. While non-nappers were neutral-to-positive regarding their post-nap satisfaction (0.8 to 1.3) and feeling (0.4 to 1.2) in our earlier work, the current study revealed them to be clearly negative, that is, they reported feeling worse after the nap relative to before it (-1.2 to -0.8), and were unsatisfied (-0.4 to -0.6).

This finding seems consistent with the fact that on DAY 2 non-nappers had a greater proportion of deep sleep, and a subsequent greater post-nap DAY 2 DST accuracy decrement than nappers, while in the earlier study they did not average more slow-wave sleep (and no performance was assessed). Of course, in the sleep-conducive environments of both studies, non-nappers had significantly less light sleep (stage 1) than appetitive nappers.

Thus, subjective ratings of nap satisfaction (and feelings relative to before the nap) and nap sleep infrastructure differences between groups appear to coincide, at least for a sleep-conducive nap environment. Appetitive nappers had the greatest amount of light sleep and the highest nap satisfaction while non-nappers had the least amount of light sleep and the lowest nap satisfaction. Moreover, when non-nappers had a greater proportion of deep sleep, their nap satisfaction was not only low, but averaged a negative value, indicating dissatisfaction.

If one assumes some causal link between these physiological, behavioral, and subjective data, then an argument can be made that the deeper nap

sleep of the non-nappers likely produces their greater post-nap performance decrement, and their negative feelings about the nap. Since naps in the alerting environment of DAY 3 radically reduced non-nappers' deep sleep percentage and post-nap DST accuracy decrement, such an argument would predict it should also have reduced non-nappers' negative feelings about that nap. However, to make such a prediction, it is necessary to ignore the fact that non-nappers indicated they were less tolerant of a noisy environment (lower PBSS scores). This latter finding could result in DAY 3 producing negative feelings in non-nappers independent of sleep infrastructure differences.

(2) Optimal versus non-optimal environmental effects. Having replicated the basic group differences in nap sleep staging and post-nap satisfaction, the effect of an alerting environment (DAY 3) on post-nap subjective ratings was assessed relative to a sleep-conducive environment (DAY 2). We originally expected that for subjects who slept on both DAYS 2 and 3, post-nap ratings would be lower (less satisfied, more fatigue, etc.) following the nap in the somewhat sleep-hostile environment.

Two-way (groups vs. DAYS) repeated measures ANOVAs were completed on each of the post-nap subjective ratings. Estimates of sleep depth and some time estimates showed no effects for groups, days, or interactions. However, most of the satisfaction, fatigue, and refreshedness ratings, within minutes of nap termination as well as nearly an hour later, showed main effects.*

*The fact that all of these post-nap rating scales showed similar main effects is perhaps not too surprising considering that post-nap satisfaction was highly correlated with "feeling now" ($r=.73$, $p<.0001$) and refreshedness ($r=.76$, $p<.0001$), and these latter two were correlated with each other ($r=.69$, $p<.0001$). Ratings of fatigue were not correlated with these post-nap ratings, however, but were correlated with sleepiness ($r=.69$, $p<.0002$), tiredness ($r=.63$, $p<.0002$), and the deactivation-sleep factor of the AD-ACL ($r=.69$, $p<.0001$).

These data are displayed in Table 7. Interaction ratios were not significant and therefore were not included in the Table.

TABLE 7

Mean subjective ratings taken 5 minutes (#1) and again 40 to 60 minutes (#2) following naps by 9 appetitive nappers (A), 9 replacement nappers (R), and 9 confirmed non-nappers (N) who slept during 60-minute afternoon nap periods on DAY 2 (sleep-conducive environment) and DAY 3 (alerting environment).

Post-nap question	Group	DAY 2	DAY 3	Groups ¹ DAYS ²	
				$\Sigma_{2,30}$	$\Sigma_{1,30}$
Percent of time asleep?	A	73.1	49.4	0.56	4.46*
	R	74.4	67.8		
	N	66.0	68.0		
#1 Nap satisfaction? (-5 to +5) ³	A	2.4	0.1	4.55*	1.81
	R	1.4	2.1		
	N	-0.4	-0.6		
#2 Nap satisfaction?	A	2.0	0.0	4.55*	3.98
	R	1.4	1.2		
	N	-0.6	-1.6		
#1 How do you feel now? (-5 to +5) ³	A	1.2	0.1	4.42*	4.08
	R	1.0	0.6		
	N	-1.2	-1.4		
#2 How do you feel now?	A	1.7	1.0	6.74*	5.83
	R	1.8	0.8		
	N	-0.8	-1.0		
#1 How fatigued now? (1 to 10) ⁴	A	4.0	3.4	1.15	0.19
	R	4.6	4.6		
	N	5.4	5.4		
#2 How fatigued now?	A	2.1	2.6	5.38*	1.42
	R	2.9	4.0		
	N	5.2	4.8		
#1 How refreshing was the nap? (1 to 10) ⁴	A	6.4	4.3	2.64	1.74
	R	4.7	4.9		
	N	3.2	3.4		
#2 How refreshing was the nap?	A	7.4	5.0	4.88*	6.58*
	R	5.9	4.9		
	N	3.0	3.2		

¹ Σ ratio for main effect between groups.

² Σ ratio for main effect within groups (across DAYS). No interaction Σ ratio was significant.

³ -5 (very negative) through 0 (neither negative nor positive) to +5 (very positive).

⁴ Fatigue was rated from 1 (no fatigue) to 10 (extremely fatigued), while refreshedness was rated from 1 (not refreshed) to 10 (extremely refreshed).

* $p < .05$ or lower.

Examination of Table 7 reveals that, contrary to our prediction of main effects due to days, subjects who slept on both DAYS 2 and 3 generally had no consistent difference in their post-nap ratings on the two days. The bulk of the significant effects were simply between-subjects (groups)

effects. Similar to DAY 2, nappers were more satisfied with their DAY 3 nap, and felt better following it, compared to non-nappers. Though groups were not significantly different in ratings of fatigue or refreshedness immediately after the naps, nappers were significantly less fatigued and more refreshed than non-nappers 40-60 minutes after the naps. It is conceivable that the initial ratings on these scales reflect the "nap inertia" we suggest is associated with the immediate post-nap performance decrements. The later ratings, at least for nappers, indicate a recovery from fatigue coincident with later performance increments.

It is noteworthy that when between-subjects F ratios were significant, the napper group showing the higher ratings on any given question varied between DAYS 2 and 3. While appetitive nappers typically averaged the most positive post-nap ratings on DAY 2, replacement nappers hold this distinction on DAY 3, at least for nap satisfaction. Furthermore, the two variables showing a main effect for days -- percent of time asleep estimates and refreshedness an hour after the nap -- were significant primarily because appetitive nappers differed significantly between nap DAYS 2 and 3 on these questions. They judged themselves to have been asleep a smaller proportion of the time on DAY 3 relative to DAY 2 ($p < .05$), though in fact they had not, and rated themselves as less refreshed an hour after the DAY 3 nap compared to DAY 2 ($p < .02$). Nevertheless, they continued to report positive feelings about the DAY 3 nap overall, and their post-nap ratings of fatigue were consistently the lowest of all groups on either day.

(3) Immediate versus delayed post-nap subjective effects. While

analyses at each subjective rating time point after naps indicated that the change in nap environment had little effect on feelings about the nap, there were some indications that if groups were assessed across both post-nap time points (6-10 mins. and 40-60 mins.) within each nap day, differences between nap DAYS 2 and 3 might emerge. Such analyses also permit an evaluation of the time-course of subjective effects following naps.

Table 8 presents the post-nap subjective rating data displayed for

TABLE 8

Mean subjective ratings taken on nap DAYS 2 and 3, 6-10 minutes post-nap and again 40-60 minutes post-nap by 9 appetitive nappers (A), 9 replacement nappers (R), and 8 confirmed non-nappers (N) who slept on both DAYS 2 and 3.

Post-nap question	Group	Mins. post-nap		Groups ¹ $\chi^2_{2,20}$	Time ² $\chi^2_{1,20}$
		6-10	40-60		
DAY 2 Nap satisfaction.	A	2.4	2.0	3.99*	1.53
	R	1.4	1.4		
	N	-0.4	-0.6		
DAY 3 Nap satisfaction.	A	0.1	0.0	3.87*	7.17*
	R	2.1	1.2		
	N	-0.6	-1.6		
DAY 2 How do you feel now?	A	1.2	1.7	4.85*	7.01*
	R	1.0	1.8		
	N	-1.2	-0.8		
DAY 3 How do you feel now?	A	0.1	1.0	3.39	5.30*
	R	0.6	0.8		
	N	-1.4	-1.0		
DAY 2 How fatigued now?	A	4.0	2.1	2.96	21.68**
	R	4.6	2.9		
	N	5.4	5.2		
DAY 3 How fatigued now?	A	3.4	2.6	1.63	8.46**
	R	4.6	4.0		
	N	5.4	4.8		
DAY 2 How refreshing was the nap?	A	6.4	7.4	8.35**	10.24**
	R	4.7	5.9		
	N	3.2	3.0		
DAY 3 How refreshing was the nap?	A	4.3	5.0	0.83	1.10
	R	4.9	4.9		
	N	3.4	3.2		

¹ χ^2 ratio for main effect between groups.

² χ^2 ratio for main effect within groups, across post-nap times.

* $p < .05$ or .025

** $p < .01$ or lower

comparisons within subjects across post-nap time points. Two-way repeated measures ANOVAs were carried out within each nap day, and F ratios for main effects are presented. No interaction effects were significant.

While nap satisfaction, as noted earlier, was lower overall among non-nappers on both DAYS 2 and 3, and though satisfaction did not change from 6-10 mins. to 40-60 mins. post-nap on DAY 2, it dropped significantly across these time points on DAY 3 due to replacement nappers becoming less satisfied later ($p < .05$), and non-nappers becoming even more dissatisfied later ($p < .05$).^{*} Appetitive nappers were somewhat neutral in satisfaction on DAY 3 at both time points.

Similar comparisons for "How do you feel now compared to before the nap?" showed that all groups, especially nappers, felt better 40-60 minutes after both naps compared to immediately after. As with satisfaction, non-nappers felt worse after nap DAY 2 than nappers, especially 40-60 minutes post-nap. However, on DAY 3 there was no main effect for groups, indicating that though non-nappers were very negative at both time points, neither napper group was significantly more positive than the non-nappers, despite the slight rise in feelings across all groups.

Ratings of fatigue showed a more consistent pattern within each day. While there were no between-group differences within DAYS 2 or 3, all groups, especially nappers, felt less fatigued 40-60 minutes after the naps compared to 6-10 minutes after the naps ($F_{1,20}=21.68$, $p < .001$; $F_{1,20}=8.46$,

^{*}Post hoc Newman-Keuls test.

$p < .01$). These changes across time resulted in appetitive nappers being significantly less fatigued than non-nappers at 40-60 mins. post-nap on both nap days (see Table 7, post hoc tests; $p < .001$ and $p < .01$), and replacement nappers being less fatigued than non-nappers on DAY 2 ($p < .01$).

Finally, ratings of refreshedness within each nap day reveal profound differences between DAYS 2 and 3. On DAY 2, appetitive nappers were more refreshed at both time points than replacement nappers ($p < .01$ and $p < .01$), and non-nappers ($p < .01$ and $p < .01$), while replacement nappers were more refreshed at both times than non-nappers ($p < .01$ and $p < .05$). In addition, both appetitive and replacement nappers had a significant increase in feelings of refreshedness from immediately after the DAY 2 nap to 40-60 minutes later ($p < .05$ in both cases). None of these effects were present on DAY 3, though nappers were slightly more refreshed than non-nappers at both time points.

Thus, the alerting environment of DAY 3 adversely affected post-nap subjective ratings somewhat more than the data in Table 7 indicated. There was some decline in satisfaction following the DAY 3 nap, relative to DAY 2, as well as less refreshedness, and somewhat less positive feelings in nappers in general. Despite these effects, however, nappers were generally positive about the DAY 3 nap, while non-nappers were unequivocally negative.

The similarity in negative feelings non-nappers expressed following naps in both a sleep-conducive and alerting environment contrasts with the dissimilar sleep infrastructure patterns they showed during these two

naps. Although the non-optimal environment of DAY 3 radically reduced non-nappers' deep sleep, while reciprocally increasing their light sleep, and though their DST immediate post-nap accuracy decrement was less severe on DAY 3, non-nappers' post-nap subjective ratings were unaffected. Were non-nappers' negative feelings strictly the result of increased deep sleep during their naps, then their DAY 3 subjective ratings should have been less negative. While it is possible the background sound of DAY 3 augmented their negative feelings about the nap, it seems reasonable to conclude from both the earlier work and our current study that confirmed non-nappers find napping unpleasant regardless of nap sleep infrastructure and napping environment.

An alternative possibility deserves consideration, however. Thus, our confirmed non-napper population was selected because they consistently reported negative consequences following naps. It would not be surprising that a group of subjects who are expecting negative effects from napping would ascribe such effects to a nap even if that particular nap did not have a physiological impact which would normally evoke negative consequences. Thus, the expectations of the confirmed non-nappers, their tendency to attribute negative consequences to naps, and their need to be consistent in ratings might all have combined to prevent them from rating the DAY 3 nap in a more positive manner.

b. Subjective effects of naps versus wake control periods. While the post-nap subjective ratings provide information on subjects' evaluation of the naps, they are unique to nap days, and consequently permit no

comparison to wake control periods. When assessing the subjective effects of naps, it is relevant to also determine the extent to which feelings change around control periods of resting wakefulness, to insure that effects observed after naps are related to subjects having slept. Moreover, in the same way that temperature provided information on subjects' state upon coming to the laboratory to nap or not nap, sleepiness and subjective activation ratings surrounding control and nap periods should indicate the degree to which individuals are prepared to nap, as well as the consequences of naps and wake control periods on these parameters. Thus, we assessed dimensions of tiredness (alertness), sleepiness, and aspects of subjective activation throughout all experimental days, and compared ratings before and after naps on DAYS 2 and 3 to those taken around wake control periods on DAYS 1 and 4.

(1) Tiredness. A 10-point self-rating scale with "Fresh as a daisy" equal to 1 and "Tired to death" equal to 10 was completed by subjects upon arriving at the laboratory and again before leaving the laboratory. The scale is an adaptation of a 7-point "alertness" scale with the same anchor point descriptors, originally reported by Aschoff, Gledke, Poppel, and Wever (1972). They indicated their version showed circadian variations in "the rhythm of alertness" (p. 137). We sought to determine if the scale would document the subjective benefits of naps for nappers.

Figure 9 graphically presents groups' mean ratings on this scale for control and nap days. Within each laboratory day the time from pre- to post-session varied between an average of 2-3 hours for control days,

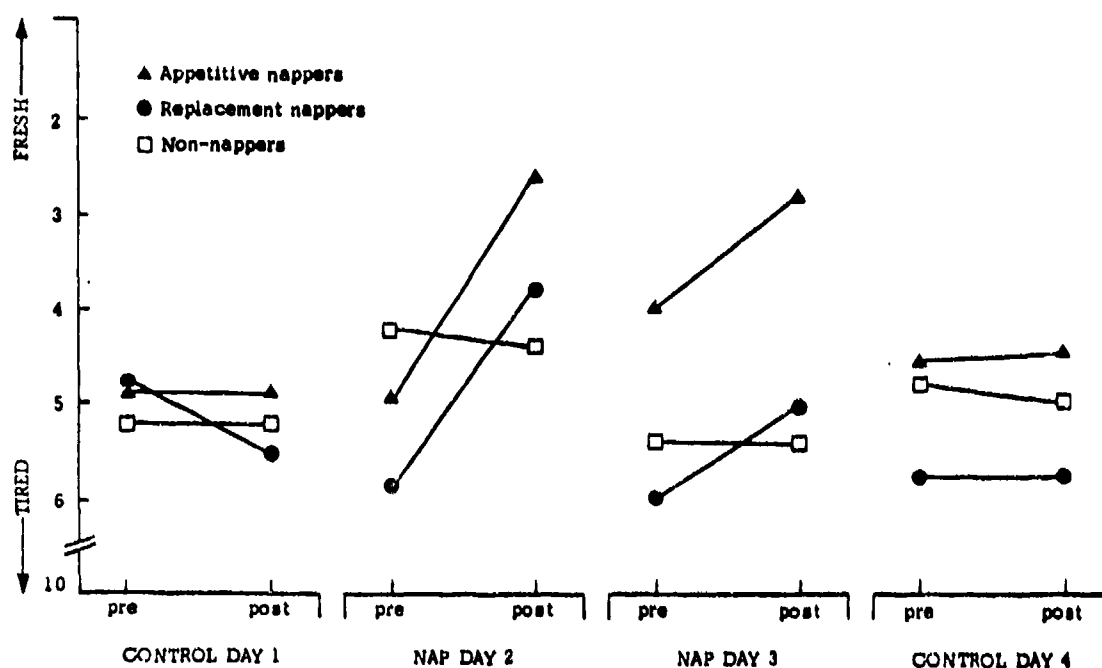


Figure 9. Mean self-ratings of tiredness on a 1 (fresh as a daisy) to 10 (tired to death) alertness scale adapted from Aschoff, Giedke, Poppel, and Weaver (1972). Values for all days are from 9 appetitive nappers, 9 replacement nappers, and 5 confirmed non-nappers who slept on both afternoon nap DAYS 2 and 3. Control DAYS 1 and 4 pre-session values are 30-45 minutes before 60-minute wake control periods, while post-session ratings are 30-45 minutes after control periods. Nap DAYS 2 and 3 pre-session values are 60-90 minutes prior to 60-minute nap periods, while post-session ratings are 30-45 minutes after nap periods.

and 3-4 hours for nap days. The graphs include the 5 non-nappers, 9 replacement nappers, and 9 appetitive nappers who slept on both DAYS 2 and 3. Changes on nap days were compared to changes across control days within each group, using treatment-by-treatment-by-subjects ANOVAs. Groups were compared within each day using groups-by-time (with repeated measures on times) ANOVAs.

The results of these analyses more than confirm the conclusions possible by visual inspection of Figure 9. On nap days, appetitive nappers had an overall main effect for time from pre- to post-session ($F_{1,24}=33.34, p<.0001$), as did replacement nappers ($F_{1,24}=9.68, p<.005$),

but neither group had significant effects across wake control days (all F ratios less than 1). Nappers, therefore, showed marked decreases in tiredness (increases in alertness) following both nap DAYS 2 and 3, relative to before naps and wake control periods.

Non-nappers, on the other hand, had no significant changes in tiredness within either nap or control days. The only F ratio greater than 1 for this group was for a main effect between nap days ($F_{1,12}=3.08$, $p<.20$), such that they were somewhat more tired on DAY 3 than on DAY 2.* This was likely indicative of the fact that non-nappers averaged significantly less TST the night before DAY 3 compared to the night before DAY 2 ($p<.05$). They apparently came to the laboratory on DAY 3 more tired, and thus more of them slept on DAY 3.

The only significant between-groups difference in these analyses was for appetitive nappers versus replacement nappers on nap DAY 3 ($F_{1,16}=10.47$, $p<.01$), such that appetitive nappers were less tired overall on DAY 3 relative to replacement nappers. Similarly, when non-nappers were included, the between-groups DAY 3 $F_{2,22}$ ratio was 5.87 ($p<.01$), with appetitive nappers less tired overall than replacement and non-nappers. Despite the appearance of appetitive nappers also being less tired than replacement nappers on control DAY 4, the effect was not significant ($F_{1,16}=1.87$).

Though both napper groups had decreases in tiredness across nap

*This was true for the 7 non-nappers who slept on DAY 3, and all 9 non-nappers as well, including the 4 who were unable to sleep on DAY 2.

days, Figure 9 suggests that the DAY 2 decreases were of a greater magnitude than the DAY 3 decreases. Indeed, analyses of combined napper groups' pre-nap versus post-nap ratings on nap days yielded an interaction that approached significance ($F_{1,51}=3.78, p < .10$). Similar to results for post-nap ratings of satisfaction and refreshedness, the alerting environment of DAY 3 somewhat attenuated alertness increments relative to the optimal environment of DAY 2. Nevertheless, nappers generally perceived themselves to be less tired after naps, while non-nappers indicated no change in alertness.

(2) Sleepiness. Just as tiredness ratings on nap days were compared to control days, sleepiness (10-pt. scale) ratings before and after naps were compared within subjects to ratings before and after wake control periods. However, unlike tiredness ratings, sleepiness was assessed repeatedly before and after naps, to track changes related to the effects of naps.

Figure 10 displays the mean sleepiness ratings for groups on wake control and nap days. The solid-line graphs for DAYS 1 and 2 are the averages for subjects in each group who slept on DAY 2, that is, 5 non-nappers, 10 replacement nappers, and 10 appetitive nappers. The broken-line graphs for DAYS 3 and 4 are the averages for subjects who slept on DAY 3, that is, 7 non-nappers, 9 replacement nappers, and 9 appetitive nappers. Changes across nap DAY 2 were compared to changes across control DAY 1 within each group, while changes across nap DAY 3 were compared to control DAY 4.

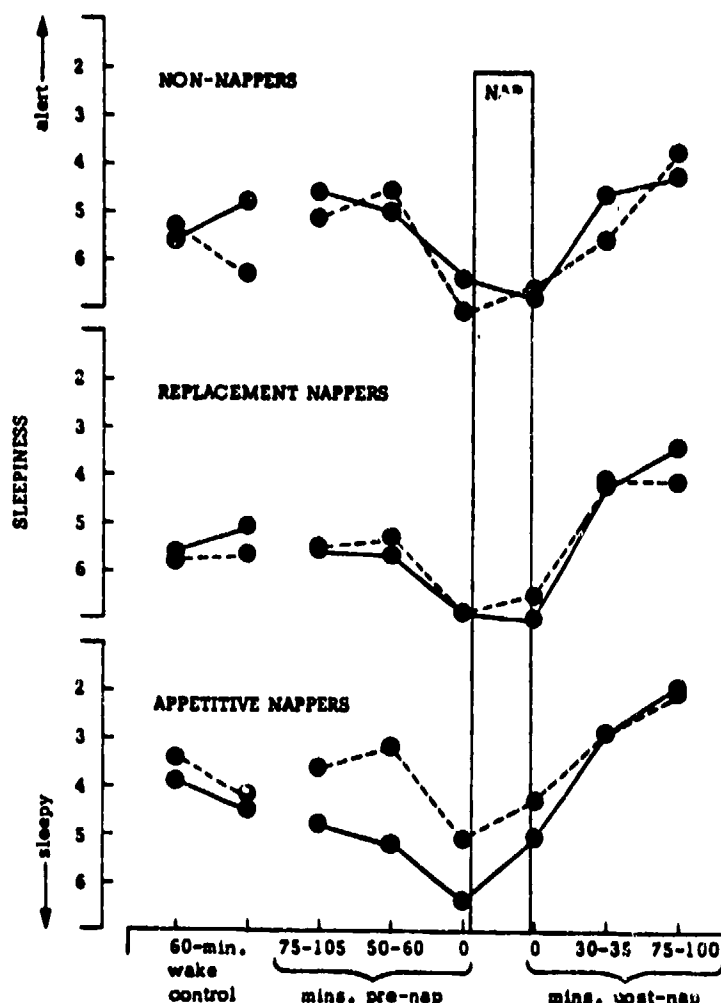


Figure 10. Mean sleepiness ratings on a 1 (wide awake, no desire to sleep) to 10 (the need for sleep is overwhelming) self-rating scale for various time points before and after 60-minute afternoon nap and wake control periods. Data for control DAY 1 and nap DAY 2 (solid lines) are from 10 appetitive nappers, 10 replacement nappers, and 5 non-nappers who slept on DAY 2. Data for control DAY 4 and nap DAY 3 (broken lines) are from 9 appetitive nappers, 9 replacement nappers, and 7 non-nappers who slept on DAY 3.

The most obvious aspects of self-rated sleepiness depicted in Figure 10 is that all groups displayed the same characteristic pattern across nap days, such that the main effect for trials (time) was significant within nap DAY 2 ($F_{5,100}=25.81$, $p<.0001$) and nap DAY 3 ($F_{5,100}=11.85$, $p<.001$). Sleepiness did not change during the roughly 30-minute period between subjects' arrival at the laboratory on nap days,

and the beginning of electrode application. However, by the end of the 50-minute period for electrode application, as the nap start time became imminent, sleepiness increased significantly in all groups, especially nappers (5 of 6 paired- t s significant at $p < .05$, two-tailed).^{*} Immediately after the 60-minute nap periods, sleepiness was similar to immediately before the naps, but by 30 minutes post-nap, all groups were significantly less sleepy relative to immediately after the naps (all paired- t s significant at $p < .05$, two-tailed), and remained so 75-100 minutes after the naps.

Comparisons between post-nap sleepiness and pre-nap, as well as control day ratings, revealed that for nap DAY 2, replacement and appetitive nappers who slept had significantly less sleepiness at both time points after the DAY 2 nap relative to before and wake control ratings (all paired- t values for both groups significant at $p < .05$, two-tailed). Of the two napper groups, appetitive nappers had the greater differences. The same comparisons for non-nappers who slept on DAY 2 revealed only one significant difference out of 8 tests, and that was between the last sleepiness rating on DAY 2 and the first rating on DAY 1 ($p < .05$).

Equivalent comparisons within groups for nap DAY 3 revealed that again, only 1 of 8 comparisons between post-nap sleepiness and both

^{*}Non-nappers who did not sleep on DAY 2 ($n=4$) did not show this preparatory decrease in sleepiness ($t=0.21$, $p>.20$), and the 5 non-nappers who slept on DAY 2 had only a slight decline in sleepiness ($t=1.36$, $p<.20$). However, the 7 non-nappers who slept on DAY 3 clearly showed the effect ($t=3.58$, $p<.02$), as did both napper groups on both nap days (all t values greater than 2.00 and significant at $p<.10$, two-tailed, or lower).

pre-nap and control day sleepiness was significant ($p < .05$) for non-nappers who slept. However, contrary to DAY 2, similar results were found for napper groups. While both replacement and appetitive nappers tended to average less sleepiness after the DAY 3 nap relative to before it and wake control DAY 4, fewer of the differences were significant within each group. Only 5 of 8 paired-comparison t -values for replacement nappers, and 3 of 8 for appetitive nappers were significant at $p < .10$, two-tailed.

The decreases in sleepiness seen following the DAY 2 nap for nappers were not nearly so evident following the DAY 3 nap. This is further evidence that the alerting environment of DAY 3 served to reduce the positive subjective effects of the nap relative to an optimal nap environment. Similar to post-nap satisfaction, refreshedness, and tiredness, sleepiness showed an effect attributable to the changed nap surroundings. As with nappers' other subjective parameters, the degree of the decrease in post-nap subjective effect was not enough to totally negate some subjective benefits from the DAY 3 nap.

Similar to other subjective ratings, especially tiredness, non-nappers who slept on nap days showed no marked decrease in sleepiness after naps. However, like nappers, they tended to show the characteristic increase in sleepiness ratings between electrode application and nap onset. The ubiquitousness of this effect is likely to be the result of the imminent demand to nap, and may reflect subject's preparation for napping. In this regard, it is noteworthy that the 4 non-nappers who did not sleep on DAY 2 did not show this increase in sleepiness immediately before the nap period ($t=0.21$, $p > .20$).

The final aspect of the sleepiness data that requires discussion concerns the only between-groups effect on this parameter. Appetitive nappers were significantly less sleepy than replacement nappers and non-nappers on DAY 3 ($F_{3,20}=6.68, p<.01$). In fact, as Figure 10 reveals, appetitive nappers were significantly less sleepy before their DAY 3 nap relative to before their DAY 2 nap ($F_{1,40}=11.11, p<.005$). This confirms a similar finding for their ratings of tiredness (see Figure 9) on DAY 3 relative to DAY 2, and is consistent with the fact that these two rating scales are highly correlated ($r=.72, p<.0001$). It appears that appetitive nappers came to the laboratory on DAY 3 less tired and less sleepy than on DAY 2, though there was no difference in their nocturnal sleep lengths the night before laboratory nap days.

(3) Subjective Activation.^{*} The deactivation-sleep factor of the AD-ACL (Thayer, 1967) includes the following adjectives: sleepy, tired, drowsy, wide-awake, and wakeful.^{**} This factor also confirmed that appetitive nappers were significantly less sleepy than replacement nappers and non-nappers on DAY 3 ($F_{2,16}=7.70, p<.005$), but not on DAY 2. Moreover, deactivation-sleep showed the same post-nap declines on DAY 2 found for sleepiness. That is, both replacement nappers and appetitive

^{*}What we refer to here as subjective activation is sometimes labeled assessment of mood (Taub et al., 1976).

^{**}The deactivation-sleep factor was positively correlated with ratings of fatigue ($r=.69, p<.0001$), sleepiness ($r=.65, p<.0001$), and tiredness ($r=.63, p<.0002$); negatively correlated with ratings of post-nap "feeling now" ($r=-.44, p<.02$), post-nap refreshedness ($r=-.38, p<.05$), and the AD-ACL general activation factor ($r=-.56, p<.0002$).

nappers had significantly less deactivation-sleepiness following the DAY 2 nap relative to pre-nap levels (paired- t values were all significant at $p < .01$ or lower). Non-nappers' post-nap values on this factor were not significantly different from their pre-nap levels.

On DAY 3, neither non-nappers nor replacement nappers had significantly different deactivation-sleepiness scores relative to either pre-nap or control periods, a finding similar to ratings of sleepiness. However, appetitive nappers averaged lower scores than their DAY 3 pre-nap value ($t=2.40$, $p < .05$), and their DAY 4 post-control period value ($t=2.43$, $p < .05$). There is some indication, therefore, that appetitive nappers had less deactivation-sleepiness after the DAY 3 nap, though basically the results on this AD-ACL factor confirm the sleepiness findings reported above. The DAY 2 results are in good agreement with Taub et al.'s (1976) report of decreased sleepiness in nappers following naps in an optimal environment, relative to wake control periods, though Bertelson (1979) was unable to confirm this.

Bertelson (1979) could also not replicate Taub et al.'s (1976) finding of increased general activation scores in nappers following naps in an optimal environment relative to a control period. (General activation includes the following adjectives: active, energetic, vigorous, lively, full-of-pep.*) While we did not find the DAY 2 post-nap general activation

*The general activation factor was negatively correlated with rating of sleepiness ($r=-.39$, $p < .05$), tiredness ($r=-.48$, $p < .01$), and the deactivation-sleep factor ($r=-.56$, $p < .001$); and uncorrelated to all other subjective ratings and AD-ACL factors.

factor scores of nappers significantly higher than their wake control periods, as Taub et al. (1976) reported, we did find that replacement nappers' and appetitive nappers' post-nap scores were significantly above their pre-nap values (Rep.: $t=3.02$, $p<.02$; $t=2.26$, $p<.05$; App.: $t=2.28$, $p<.05$; $t=2.98$, $p<.02$). Similar to sleepiness, non-nappers showed no significant increases in general activation following their DAY 2 naps. On DAY 3, no group had post-nap general activation values that were significantly above either their pre-nap levels or wake control periods.

While Bertelson (1979) could not replicate Taub et al.'s (1976) finding of decreased deactivation-sleepiness and increased general activation following naps by habitual nappers, she did show significant effects on the other two factors of the AD-ACL, namely, high activation and general deactivation.* High activation includes the adjectives of jittery, intense, fearful, clutched-up, and tense. Bertelson found this factor reduced following naps by nappers and bedrest by non-nappers, while general deactivation (placid, calm, at rest, still, quiet) was increased following naps by nappers and bedrest by non-nappers.** Taub et al. (1976) reported no effects on these factors. Our data provide some support for both positions.

We did not find significantly less high activation following naps by any group, relative to pre-nap levels as Bertelson (1979) reported. However,

*In our study these two AD-ACL factors were uncorrelated with all other subjective measures, and only slightly (negatively) correlated to each other ($r=-.34$, $p<.06$).

**It is noteworthy that Bertelson (1979) also found significant effects within and between groups in mood as assessed by the Multiple Affect Adjective Checklist (Zuckerman & Lubin, 1965).

appetitive nappers averaged significantly less high activation after both nap DAYS 2 and 3, relative to their wake control periods (DAY 2: t s ranged from 2.31 to 3.12, $p < .05$ or lower; and DAY 3: t s ranged from 2.07 to 3.27, $p < .10$ or lower, two-tailed). Though replacement nappers and non-nappers were in the same direction, their results were not significant. The 4 non-nappers who did not sleep on DAY 2 also did not show the effects.

Unlike all other AD-ACL factors, general deactivation did not change significantly across nap periods for any group relative to either pre-nap or control day levels. Nonetheless, there was one significant main effect of groups on this factor, 35 minutes after naps ($F_{2,20}=3.56$, $p < .05$). Following naps, non-nappers were less calm, as assessed by this factor than nappers. Post hoc Newman-Keuls comparisons between means revealed that neither napper group was significantly above non-nappers' values on DAY 2, but following the DAY 3 nap, both appetitive ($p < .05$) and replacement nappers ($p < .05$) were higher in general deactivation compared to confirmed non-nappers.

When AD-ACL factor scores at various points on nap days were compared to equivalent points on wake control days, a consistent pattern emerged at one particular time point that coincides with an aspect of sleepiness ratings presented above. The AD-ACL factor scores immediately prior to the nap periods were significantly different from the factor scores immediately prior to wake control periods. Immediately prior to nap DAYS 2 and 3, compared to control DAYS 1 and 4, subjects averaged less general activation ($F_{3,60}=5.96$, $p < .005$), less high activation ($F_{3,60}=7.29$, $p < .001$),

and more general deactivation ($F_{3,60}=3.10, p<.05$). The effects appeared equally distributed among groups. Just as sleepiness ratings increased immediately prior to naps (see Figure 10), so activation declined and calmness increased.

We speculated above that these changes may reflect a preparatory response for napping. Since the changes were not observed either on control days or in the 4 non-nappers who did not nap on DAY 2, we continue to view the preparatory response as the most parsimonious explanation for the phenomenon. What makes this view even more compelling is that nappers had significantly lower body temperatures prior to nap days compared to wake control days (see Figure 5). Thus, both physiological as well as subjective indices of activation indicate that nappers have lowered activation prior to napping. While it may be possible to suggest this is the result of partial sleep deprivation among our replacement nappers, this explanation cannot account for the effect among appetitive nappers who obtained as much nocturnal sleep before laboratory nap days as before wake control days.

In summary, the subjective data present a remarkably consistent picture that is indicative of the high intercorrelations among various subsets of subjective measures. Nappers derive subjective benefits from napping in the form of increased refreshedness, feeling better, less fatigue, less tiredness, less sleepiness, and increased activation, relative to before naps, and periods of quiet resting activity. Confirmed non-nappers, on the other hand, appear to derive no clear subjective benefits from napping,

though no unequivocally negative consequences for them were evident either. Appetitive nappers appear to derive the most subjective benefits, at least for naps in an optimal environment. While a non-optimal environment slightly reduced the positive feelings and increases in activation following naps by nappers, on the whole nappers continued to report subjective benefits from naps, even in the alerting environment. Whereas more confirmed non-nappers were able to sleep in the alerting (than in the optimal) environment, they rated the consequences of that nap as negative as those of the nap taken in the sleep-conducive environment. All subjects, particularly nappers, showed an increase in sleepiness and a decrease in activation ratings immediately before naps indicative of a preparatory response to napping.

D. Results from Data Collected outside the Laboratory.

Since we sought to investigate the functions served by napping in young adults selected for their diverse napping patterns, it seemed reasonable to confirm the actual napping patterns of our subjects, outside the laboratory, in the broader contexts of daily activity, nocturnal sleep, circadian fluctuations in activation, and sleep need. Moreover, we felt such data could potentially be of value in understanding some of the differences observed in the laboratory. The major impediment to gathering such data, however, was gaining the full cooperation of subjects in keeping detailed daily sleep diaries, and circadian logs. While this required a great deal of effort, the 99% data return, the detailed nature of the data, and especially the findings from the data more than compensated the effort.

The following sections contain the results on the relationships between napping, circadian cycles, and sleep need in appetitive nappers, replacement nappers, and confirmed non-nappers. The data provide insights into the functional significance of napping for these subjects, and permit a greater understanding of aspects of the data collected in the laboratory.

1. Circadian Variation on Nap and Non-nap Days.

During the 14-day period between nap DAY 3 and control DAY 4, subjects were asked to record their oral temperature and complete the AD-ACL (Thayer, 1967), five times a day: upon arising in the morning, noon, 3:30 p.m., 7:30 p.m., and just before retiring at night. Subjects

adhered to these recording times fairly well, and there were no differences between groups in mean time of any recording. For all subjects, the average recording times were: 9:40 a.m., 12:40 p.m., 4:10 p.m., 8:10 p.m., and 1:25 a.m.

Single values on each variable were generated for individual subjects by averaging all values at a given recording time, yielding one value for each of the five recording times for each subject. Group values at each time point were calculated by taking the median score of all subjects on a parameter. These data were then analyzed non-parametrically,* using Wilcoxon matched-pairs signed-ranks and Mann-Whitney \bar{U} -tests, to avoid making assumptions about data distributions, since data were collapsed both within and between subjects.

Since the sleep diary was also completed during this 14-day period, it was possible to separate the circadian data of nappers into nap day functions and non-nap day functions, to investigate differences in activation on days subjects napped relative to days they did not nap. Figure 11 displays the resulting circadian functions for temperature and the four subjective activation factors, for nap days and non-nap days of appetitive and replacement nappers. Since non-nappers did not nap during the 14-day period,** their data reflect only non-nap days.

*The minimum significance level was $p < .05$. All comparisons reported are for two-tailed levels of significance.

**Though three of the non-nappers reported napping more than once during this period, the proportion of non-napper naps was too small to allow reliable nap day circadian functions to be generated. Nevertheless, the non-napper data presented in this section includes only their non-nap days.

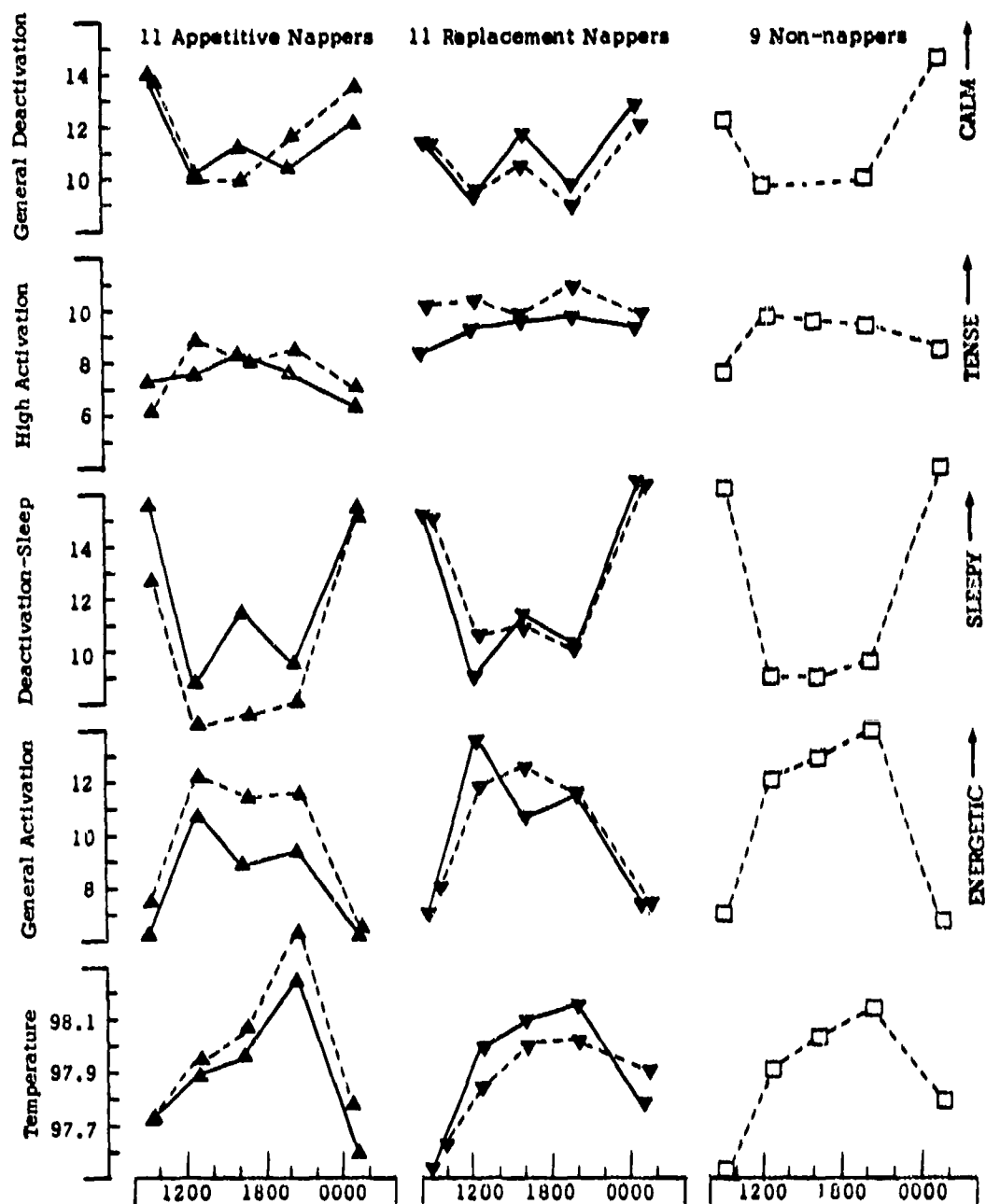


Figure 11. Circadian curves for oral temperature and four subjective activation factors from the AD-ACL (Thayer, 1967) on nap days (—) and non-nap days (----) during a 14-day period.

a. Oral temperature. Temperature curves are presented as the bottom graphs on Figure 11. Overall, the curves reflect a circadian variation, regardless of group or day. The greatest changes occur from upon arising to noon, and from 8:00 p.m. to just before bedtime ($p < .0001$ in all cases). In addition, similar to detailed recordings of diurnal variation in temperature (Colquhoun, 1971), the peak temperature in each of these curves is between 7:30 p.m. and 8:30 p.m.

The most notable aspect of the functions appears to be appetitive nappers' characteristically large temperature increase from 4:00 p.m. (1600) to 8:00 p.m. (2000), on both nap and non-nap days, relative to replacement nappers and non-nappers. Since the functions for nap and non-nap days were not significantly different within respective napper groups, analyses of daytime temperature changes were conducted on the data for all days combined. Wilcoxon matched-pairs signed-ranks tests between the three midday recordings within each group revealed that no group had a significant rise in temperature from 12:30 p.m. (1230) to 4:00 p.m. (1600). However, appetitive nappers had a significant increase from 4:00 p.m. to 8:00 p.m. ($n'=11$, $T=3$, $p < .01$), while replacement nappers ($n'=11$, $T=37$) and non-nappers ($n'=9$, $T=10$) did not. Despite this, appetitive nappers' median temperature at 8:00 p.m. was not significantly above the other groups. When comparisons were made between 12:30 p.m. and 8:00 p.m., both appetitive nappers ($T=8$, $p < .05$), and non-nappers ($T=2$, $p < .01$) had significantly higher temperatures at the 8:00 p.m. recording, though replacement nappers ($T=14.5$) did not.

Replacement nappers' temperature curve was, therefore, somewhat flattened relative to appetitive nappers' curve, and showed no significant increase from noon to early evening. This is not inconsistent with temperature data collected in the laboratory, where replacement nappers tended to have the lowest temperatures during the afternoon, while appetitive nappers' temperatures were less likely to drop across naps, and were not as low overall, especially on DAY 3.

The one prediction we had made regarding circadian temperature was that non-nappers were expected to have significantly higher temperatures, at least during the afternoon, than either of the napper groups' nap days, especially replacement nappers. This was based on non-nappers' higher laboratory temperatures during both our earlier and current studies (see Figure 4). This prediction was not confirmed. Examination of Figure 11 reveals no difference between groups.

It would appear that it is incorrect to conceptualize confirmed non-nappers as "poor" daytime sleepers, analogous to Monroe's (1967) poor nighttime sleepers, whom he found to have not only higher body temperatures throughout the night but higher autonomic arousal in general. The lack of differences between groups suggests non-nappers are not "daytime insomniacs." Of course, more frequent temperature measurements during the day might have revealed subtle differences. Overall, however, as we measured it, there seems to be no fundamental difference in absolute levels, amplitude, or phase of the temperature rhythm between nappers and non-nappers, with the exception of appetitive nappers' midday function.

b. Subjective activation (AD-ACL).

(1) General activation and deactivation-sleep. These factors relate to the degree to which individuals report feeling energetic and sleepy, respectively, and, consequently, are generally negatively correlated (Clements et al., 1976, have indicated that they are opposite ends of a continuum rather than orthogonally related). Indeed, the laboratory data presented above showed these two factors to be inversely related. Circadian curves for the factors are presented in the middle of Figure 11.

As with oral temperature, the most noticeable difference in these factors involved appetitive nappers. Specifically, they were significantly less generally activated at 4:00 p.m. on nap days relative to non-nap days ($T=1$, $p<.01$), and they reported significantly more sleepiness on nap days, upon arising ($T=3$, $p<.01$), at noon ($T=4$, $p<.01$), and at 4:00 p.m. ($T=2$, $p<.01$). In contrast, replacement nappers had no significant differences in these factors between nap and non-nap days.

Moreover, Mann-Whitney U -tests between groups revealed that on nap days appetitive nappers were less generally activated at 4:00 p.m. than replacement nappers' nap days ($U=30$, $p<.05$) and non-nap days ($U=20$, $p<.02$), and non-nappers' non-nap days ($U=6$, $p<.002$). Appetitive nappers were also less activated on nap days at 8:00 p.m., relative to replacement nappers' nap days ($U=18.5$, $p<.02$) and non-nap days ($U=27$, $p<.05$).

A similar pattern of between-group differences at midday was

seen for deactivation-sleep, though in this case the curve that was clearly different was appetitive nappers' non-nap day values. Not only were their non-nap day values prior to 8:00 p.m. significantly below their nap day values, but they were also below replacement nappers' nap days at noon ($U=30$, $p<.05$), and 4:00 p.m. ($U=7$, $p<.002$); replacement nappers' non-nap days at noon ($U=14$, $p<.002$), 4:00 p.m. ($U=9.5$, $p<.002$), and 8:00 p.m. ($U=13$, $p<.002$); and non-nappers' non-nap days at noon ($U=18$, $p<.02$).

Thus, appetitive nappers were less sleepy at noon on their non-nap days, relative to all other noon values, and were less sleepy at 4:00 p.m. than replacement nappers. Conversely, appetitive nappers were less activated on nap days, at 4:00 p.m., relative to all other 4:00 p.m. medians, and were less activated at 8:00 p.m. than both replacement nappers' values.

This is an unexpected finding. Appetitive nappers were selected based upon their reporting they nap "even when they don't feel tired." Yet these data indicate that they are significantly less generally activated at 4:00 p.m., which is when the bulk of their naps are taken (77% between 2:00 p.m. and 8:00 p.m.). On the other hand, they are not necessarily more sleepy on nap days compared to replacement nappers and non-nappers. Rather, it is on non-nap days that the appetitive nappers appear to be extremely un-sleepy, at least from noon to 4:00 p.m. While the lowered general activation on nap days may reflect their preparation for napping -- if not their reason for napping -- the lowered sleepiness on

non-nap days may reflect their inability or lack of desire to nap on those days.

In terms of sleepiness, we doubt that the low ratings characteristic of noon and 4:00 p.m. on appetitive nappers' non-nap days are indicative of an inability to nap. There are two reasons for this. First, on nap DAY 3, appetitive nappers had significantly less self-rated tiredness (see Figure 9), less sleepiness (see Figure 10), and less AD-ACL deactivation-sleepiness. Nevertheless, 9 of 11 napped on DAY 3. The circadian deactivation-sleep values at noon, 4:00 p.m., and 8:00 p.m. for appetitives' non-nap days are virtually identical to their afternoon deactivation-sleep values on laboratory DAY 3, while their nap day values are identical to their laboratory DAY 2 values. Thus, they may be profoundly less sleepy on certain days, and therefore choose not to nap, but if asked to nap, even in an alerting environment, they can do so, and derive benefits from it.

This account of the laboratory and circadian sleepiness data of appetitive nappers also dovetails with an SSSP question that consistently separates appetitive nappers from replacement nappers and non-nappers. When asked, "Could you nap almost anytime during daytime hours?" appetitive nappers respond very affirmatively, while replacement nappers respond with uncertainty. This was true for subjects in our study both six months before the laboratory sessions (A vs. R , $p < .01$), and again at the last laboratory session ($p < .025$), and is consistent with prior work (see Evans, 1976). Similarly, appetitive nappers responded

consistently more positively to questions concerning whether they could fall asleep on a train, plane, car, etc. ($p < .001$), as well as whether or not they would prefer a few short naps per 24-hour period to one continuous nocturnal sleep period ($p < .05$). Clearly, they prefer to nap and can nap in a wide variety of circumstances, and thus their profound lack of sleepiness on certain days appears to be associated with a lack of desire to nap, rather than an inability to nap.

Though the appetitive nappers' circadian fluctuations in activation and sleepiness were to some extent unexpected, another aspect of these data that was significant had been predicted. We had hypothesized that nappers should experience a drop in general activation and a reciprocal rise in sleepiness prior to their naps relative to non-nap days. The most likely place for these effects to be revealed would be the time between the noon and 4:00 p.m. recordings, that is, during the proverbial post-prandial dip, and shortly before the majority of naps. Even if nap and non-nap days were not significantly different at noon and 4:00 p.m. values, the change across this time should be greater and in the predicted direction on nap days.

As Figure 11 shows, both appetitive and replacement nappers displayed a drop in general activation and a reciprocal rise in sleepiness from noon to 4:00 p.m. on nap days, but not on non-nap days. Non-nappers showed neither effect. Table 9 presents the median change score across this time period for nap days and non-nap days of nappers and non-nappers. Wilcoxon tests were carried out within each group on

TABLE 9

Median change in AD-ACL factors' scores from noon to 4:00 pm for nap days and non-nap days of appetitive nappers, replacement nappers, all nappers, and non-nappers during a 14-day period.

	N	nap days 1200-1600	non-nap days 1200-1600
Factor: <u>General Activation</u>			
Appetitive nappers	11	-2.00*	+0.22
Replacement nappers	11	-1.20*	-0.21
All nappers	22	-1.66**	+0.03
Non-nappers	9	-----	-0.15
Factor: <u>Deactivation-Sleep</u>			
Appetitive nappers	11	+1.09	+0.40
Replacement nappers	11	+2.25*	+0.19
All nappers	22	+1.67**	+0.30
Non-nappers	9	-----	-0.51
Factor: <u>High Activation</u>			
Appetitive nappers	11	+0.83	-0.76
Replacement nappers	11	+0.35	-0.62
All nappers	22	+0.49	-0.69
Non-nappers	9	-----	-0.25
Factor: <u>General Deactivation</u>			
Appetitive nappers	11	+1.08*	+0.57
Replacement nappers	11	+1.50*	-0.92
All nappers	22	+1.43**	+0.30
Non-nappers	9	-----	+0.08

*Wilcoxon test between 1200 and 1600 values within nap days yielding a T value significant at $p < .05$.

** T value significant at $p < .01$.

the noon versus 4:00 p.m. data. The changes that were significant are asterisked in Table 9.

It seems clear that nappers did indeed experience less energy and greater sleepiness during the post-prandial period of nap days, but not non-nap days. While the effect appeared more robust for general activation in appetitive nappers, the replacement nappers showed the greater effect in sleepiness. In fact, appetitive nappers did not actually have a significant increase in sleepiness on nap days, though when combined with replacement nappers, all 22 nappers together changed significantly ($T=34.5$, $p<.01$). Conversely, no single group or combination of subjects had significant changes on non-nap days.

(2) General deactivation and high activation. Like general activation and deactivation-sleep factors, nappers also had a significant increase in general deactivation (calmness) from noon to 4:00 p.m. on nap days, but not non-nap days. And again, non-nappers showed no change. Table 9 details the change scores on this factor, as well as the high activation (tenseness) factor, which did not show significant effects for groups or nap days, though Figure 11 suggests appetitive nappers might be lower than the other two groups overall.

The only high activation difference occurred within replacement nappers, upon arising in the morning, where they had significantly lower high activation on nap days relative to non-nap days ($T=11$, $p<.025$). Interestingly, this is the only group and only time point where the information was completed at significantly different times. That is, replacement

nappers, as will be detailed below, awoke consistently earlier on the morning of nap days relative to non-nap days, and this is reflected in the median time they indicated they completed the AD-ACL booklet (nap days = 8:50 a.m. versus non-nap days = 9:34 a.m., $p < .025$). Thus, it is uncertain whether replacement nappers' lower high activation early in the mornings of nap days is the result of a circadian influence on the rating, or is meaningfully related to how well they slept the night before or whether they plan on napping later in the day.

The post-prandial increase in general deactivation on appetitive nappers' nap days resulted in their 4:00 p.m. value being significantly higher (i.e., more calm) on nap days relative to their non-nap days ($T=10$, $p < .025$), and significantly above non-nappers' non-nap days value ($U=20$, $p < .05$). This is consistent with appetitive nappers' very low general activation at 4:00 p.m. on nap days, and further emphasizes that their typical pre-nap state is one of lowered energy and increased calmness.

The increase in general deactivation, and deactivation-sleep, as well as the decrease in general activation that replacement and appetitive nappers report between noon and 4:00 p.m. on nap days, appears somewhat analogous to the increase in sleepiness (see Figure 10) and general deactivation, and decrease in general activation and high activation seen in the laboratory between an hour before the naps and immediately before the naps. Though the laboratory changes were over a much more circumscribed time frame and may have been a function of experimental

demands, the similarity seems worthy of note. The fact that the laboratory changes were not seen on wake control days and the circadian changes were not seen on non-nap days increases the likelihood that these changes are indicative of a preparatory response to nap. However, they could also reflect sleep need, though the concept of sleep need should then be confirmed by shortened nocturnal sleep. Analyses of sleep diary data provided information relevant to this issue.

2. Sleep Diary Results.

The 30-day sleep diary subjects completed between laboratory DAYS 1 and 4 permitted evaluation of the typical behavioral activity and sleep/wakefulness patterns of nappers and non-nappers, and comparison of appetitive and replacement napping patterns. The diary also allowed comparisons of nap and non-nap days (a procedure employed in our earlier study [Evans & Orne, 1975]) to determine the function of napping in the broader context of sleep need, and it provided important information on nocturnal sleep surrounding the laboratory naps.

a. Behavioral activity in nappers and non-nappers. The sleep diary contained a number of questions that referred to physical activity, mental activity, and fatigue. Though we had no clear hypotheses concerning between-group differences in these areas, we nevertheless thought it important to assess such activity in the event that it accounted for napping behavior.

Since modern restorative theories of sleep (e.g., Oswald, 1970) place emphasis on energy consumption during wakefulness, they also

therefore predict changes in sleep infrastructure as a result of changes in daily physical activity. Indeed, over a dozen separate studies have been carried out on the effect of energy expenditure (usually exercise) on sleep, with varying results. Bonnet (1980) lists these studies, and reports a well-controlled investigation he conducted, which shows performance and mood decrements following wake energy expenditure equivalent to 40 hours of sleep deprivation. The decrements he observed closely approximated sleep deprivation decrements, but unlike sleep deprivation, nocturnal sleep following the exercise was unchanged.

Lack of clear effects from such energy expenditure on sleep might suggest that different levels of physical activity are unrelated to whether an individual naps or not. That is, napping may be the sole result of sleepiness, reflecting sleep need, largely independent of fatigue from energy expenditure. If this is the case, then nappers and non-nappers should not differ in their patterns or amounts of physical activity.

Table 10 displays the mean 30-day sleep diary answers to questions concerning behavioral activity in both napper groups and confirmed non-nappers. The between-groups F ratios are also presented, along with post hoc Newman-Keuls comparisons. Clearly, groups did not appear to differ in the frequency of physical or mental activity, or related questions. More detailed analyses of physical activity patterns, including the type of activity, time of day, duration of activity, etc., also revealed no differences between nappers and non-nappers.

TABLE 10

Mean sleep diary responses to questions regarding behavioral activity over a 30-day period for appetitive nappers (A), replacement nappers (R), and non-nappers (N).

Sleep Diary Question	N=	A 11	R 11	N 9	Groups ¹ $F_{2,28}$	post-hoc ² results
Read or watch TV before going to sleep last night? (Y=1, N=0)		0.35	0.34	0.48	0.81	
How long were you outdoors yesterday? (hrs:mins)		1.37	2.28	2.23	1.69	
Any regular physical exercise yesterday? (Y=1, N=0)		0.28	0.25	0.25	0.05	
Any special physical exercise yesterday? (Y=1, N=0)		0.14	0.23	0.15	0.80	
Did you concentrate especially hard yesterday? (Y=1, N=0)		0.29	0.27	0.30	0.12	
Did you have any difficulty concentrating? (Y=1, N=0)		0.18	0.19	0.24	0.50	
Time you felt most tired yesterday?		1651	1814	1627	2.41	
At any time yesterday were you fighting off sleep? (Y=1, N=0)		0.23	0.26	0.26	0.18	
How many cups of coffee or tea did you have yesterday?		0.73	1.48	2.08	2.61	
How many cups of coffee or tea in the last 3 hours?		0.04	0.13	0.39	6.01*	A, R < N

¹ F ratio for main effect between groups.

² Newman-Keuls comparisons between means, $p < .05$ or lower.

* $p < .01$

The only significant F ratio was for the number of cups of coffee or tea in the last three hours, with non-nappers reporting more coffee-tea consumption than either napper group ($p < .05$). While there was a similar trend for coffee-tea consumption during the entire day, it was not significant. Furthermore, when stimulant consumption (e.g., tobacco, coffee, tea) was assessed on other questions during the study, groups did not differ significantly, though there remained a pattern of non-nappers taking slightly more coffee than appetitive nappers.

The significant F found for coffee consumption in the last three hours was associated with significant differences in the times subjects

completed the sleep diary each day. While they were all asked to complete it shortly after awakening in the morning, appetitive nappers did so significantly sooner than replacement nappers ($p < .10$) and non-nappers ($p < .05$). In fact, non-nappers completed the diary an average of 3 hours and 46 minutes after awakening, compared to appetitives' 1 hour and 5 minutes ($p < .05$). It is possible that non-nappers had more time in which to drink coffee (prior to diary completion), and consequently reported more coffee consumed within the last three hours.

Groups not only did not differ consistently in coffee intake, but they also did not differ in their medicinal drug intakes or their illicit drug consumption, both of which appeared surprisingly low. No group consistently used aspirin, tranquilizers, sleeping pills, or similar sleep aids to go to sleep, and conversely, no group consistently used No-Doz and stimulants to stay awake. Finally, groups did not differ in physical characteristics such as height (5'5" - 6'1") and weight (115 - 180 lbs.).

b. Characteristics of nighttime and daytime sleep in nappers and non-nappers. Just as we did not anticipate differences in behavioral activity between nappers and non-nappers, we did not expect to find nocturnal sleep differences between them. However, we understandably expected the 30-day diary to document that nappers napped frequently during the daytime, relative to non-nappers, with appetitive nappers napping the most.

Aside from confirming the daytime napping patterns of our subjects, examination of the diary sleep/wakefulness patterns, as well as

nocturnal sleep characteristics in our nappers and non-nappers, was essential to insure napping differences were not the product of profound nocturnal sleep differences. For example, one might view our daytime nappers as nocturnal insomniacs, who must sleep in the day to compensate for an assumed inability to go to sleep or maintain sleep during the night. Alternatively, one could argue that confirmed non-nappers do not nap because they are insomniacs at all times, and thus also have poor nocturnal sleep efficiency. While we have maintained that replacement nappers likely nap to compensate for lost nocturnal sleep (Evans & Orne, 1975), we have suggested this lost night sleep resulted from their voluntary shortening of sleep due to perceived work demands rather than any sleep problems. Further, in this study we eliminated all subjects who reported difficulty with nocturnal sleep. Consequently, we expected normal nocturnal sleep characteristics in all groups.

Table 11 presents the mean nocturnal and daytime sleep parameters during the 30 days, for all 3 groups, along with between-group F ratios, and post hoc tests. As predicted, there were no differences in nocturnal sleep patterns, and all subjects appeared normal and non-insomniac. They all tended to go to bed around the same time (non-nappers were slightly later on the average), fall asleep fairly quickly, sleep well, not wake up or get up during the night, sleep around 7 hours, and awake about the same time of the morning. They felt they dreamt about 60% of the time, and recalled about 60% of the dreams (replacement nappers

TABLE 11

Mean sleep diary responses to questions regarding nocturnal sleep and daytime napping over a 30-day period for appetitive nappers (A), replacement nappers (R), and non-nappers (N).

Sleep Diary Question	N=	A 11	R 11	N 9	Groups ¹ F _{2,28}	post-hoc ² results
Did you sleep well last night? (Y=1, N=0)		0.91	0.88	0.77	2.17	
How deeply did you sleep? (1-10)		7.58	7.48	6.85	0.70	
What time did you go to sleep last night?		0156	0146	0229	2.51	
How long to fall asleep? (mins)		15.9	14.7	19.0	0.46	
Did you wake up during the night? (Y=1, N=0)		0.31	0.31	0.17	1.82	
Did you get up during the night? (Y=1, N=0)		0.11	0.12	0.12	0.02	
Did you dream? (Y=1, N=0)		0.62	0.61	0.54	0.22	
Do you recall the dream? (Y=1, N=0)		0.64	0.52	0.78	3.28	
How long did you sleep last night? (hrs:mins)		7:12	7:07	6:49	1.30	
What time did you wake up this morning?		0910	0904	0907	0.03	
Did you nap yesterday? (Y=1, N=0)		0.40	0.29	0.05	21.04 *	A>R>N
How long was the nap? (hrs:mins)		1:08	1:22	1:14	0.67	
Was the nap a good one? (Y=1, N=0)		0.81	0.84	0.35	10.22 *	A, R>N
Were you refreshed after the nap? (Y=1, N=0)		0.73	0.83	0.32	10.97 *	A, R>N
I napped lying down (1), sitting up (2).		1.15	1.28	1.32	2.14	

¹ F ratio for main effect between groups.

² Newman-Keuls comparisons between means, $p < .05$ or lower.

* $p < .001$

appeared to recall somewhat fewer dreams than non-nappers).^{*} Not only were the mean differences presented in Table 11 non-significant, but comparison of each group's variance on each diary question (using Hartley's F_{\max} test) also showed no differences.

In addition to the sleep diary confirming no differences between nappers and non-nappers in nocturnal sleep patterns, questionnaires administered in the laboratory also revealed a lack of differences. In particular, the morningness-eveningness questionnaire, developed by Home and Ostberg (1976) for the purpose of assessing differences in circadian sleep/wakefulness rhythms, yielded no significant between-group difference (appetitives' $\bar{X}=42.55$; replacements' $\bar{X}=44.27$; non-nappers' $\bar{X}=41.78$). All three groups had some evening types, and no morning types, with the majority of subjects being neither type. The fact that Webb and Bonnet (1978) have reported differences in the sleep and napping patterns of extreme morning and evening types makes our result all the more important, since it appears this parameter cannot account for our napper - non-napper napping differences.

Finally, personality questionnaires, such as Zuckerman's Sensation-Seeking Scale (Zuckerman, Kolin, Price, & Zoob, 1964) and the Maudsley Personality Inventory (Eysenck, 1956, 1959), revealed no differences between groups, further confirming that neither nappers nor non-

^{*}All diary data were analyzed for differences between weekdays and weekends. The only significant difference was that appetitive nappers awoke 45 minutes later on weekend mornings relative to weekday mornings ($T=4$, $p<.01$).

nappers have personality characteristics similar to those reported for insomniacs (Coursey, Buchsbaum, and Frankel, 1975). Other inventories, such as Barron's (1953) Ego Strength scale from the MMPI, the socialization scale (Gough, 1960) from the CPI, and the Crowne-Marlowe Social Desirability scale (Crowne & Marlowe, 1960) also showed no differences between groups nor any abnormal scores. It is noteworthy that Lawrence (1971) also found no personality differences between nappers and non-nappers.

Returning to the diary data presented in Table 11, it is clear that the only area showing major differences between groups involved, as expected, questions concerning daytime napping, where the F ratios were significant at $p < .001$ or lower. Appetitive nappers reported napping on 40% of the days, which was significantly above replacement nappers' 29% ($p < .05$), both of which were higher than non-nappers' 5% ($p < .001$). The typical nap duration was slightly over an hour in all groups. However, judgments of whether or not the nap was good and refreshing revealed nappers to be significantly more positive than non-nappers ($p < .001$ in all cases). The similarity of these subjective effects to those found following the laboratory naps (see Table 7) leaves little doubt that our confirmed non-nappers do indeed find naps very unpleasant, and actively avoid napping, while nappers nap frequently and report very positive effects from over 80% of their naps.

c. Napping patterns in appetitive and replacement nappers. The sleep diary also included information on the characteristics of daytime

sleep in our two napper groups. Table 12 displays the total number of naps for each group during the 30-day period.* Consistent with the

TABLE 12

Appetitive (A) and replacement (R) nappers' nap parameters taken from sleep diaries during the 30-day period between laboratory DAYS 1 and 4.

	A	R	Mann-Whitney ¹
Total number of naps	181	131	
Number of naps per subject	17	11	$U=28, p<.025$
Number of naps per week per subject	3.2	2.6	$U=34, p<.05$
Percent of naps between 1200 and 1800	72%	72%	
Time of nap	1554	1625	$U=34.5, ns$
Nap duration (mins)	60	90	$U=51, ns$
Time from morning awakening to nap onset (hrs:mins)	7:08	7:57	$U=50, ns$

¹ Two-tailed tests.

predictions, appetitive nappers had significantly more naps per subject, and more naps per subject per week, a result in full accordance with survey nap frequency data reported by hundreds of replacement and appetitive nappers (see Figure 3).

Though it appeared that appetitive nappers had an earlier nap onset time, the difference was not significant, nor were nap duration and time from morning awakening to nap onset significantly different between

*The values presented in Tables 12 and 13 are medians, and the statistical analyses are nonparametric, since the data are the result of pooling within and between subjects and we did not wish to make assumptions regarding the nature of the data distributions. Nevertheless, all significant comparisons were confirmed parametrically.

appetitive and replacement nappers. Figure 12 contains the distribution of each group's naps (nap onset time) across the time of day. The slight

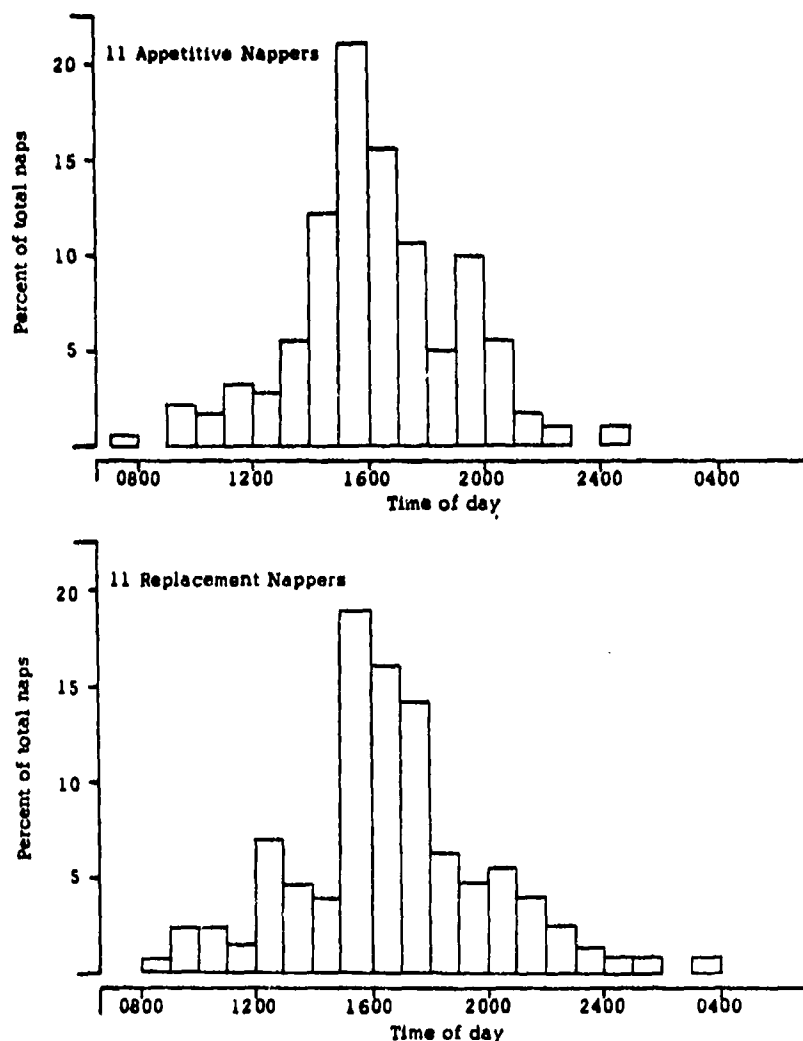


Figure 12. Proportion of naps distributed across time of day for appetitive nappers' 181 naps, and replacement nappers' 131 naps. Data are from the 30-day sleep diaries completed between laboratory DAYS 1 and 4.

tendency for appetitive nappers to begin naps somewhat earlier in the day was largely a function of their having more naps begin between 2 and 3 p.m., relative to replacement nappers ($p < .05$), while the latter group tended to have more naps later in the evening, that is, after 9 p.m. Despite replacement nappers' nap onset times appearing somewhat more variable,

both groups had roughly three quarters (72%) of their nap onsets during the afternoon, between noon and 6 p.m., with the highest proportion of naps (over 33%) in the middle of the afternoon, between 2:30 p.m. and 4:30 p.m.

The higher frequency of napping among appetitive nappers is consistent with their reports of being able to fall asleep almost any time of day, and while riding in a car, bus, airplane, or train, as well as their greater desire for a few short naps per 24-hour period relative to one continuous period of sleep. It must be emphasized that these individuals are not narcoleptic, since they clearly do not experience uncontrolled sleep onset. Rather, they appear to have increased control of sleep onset, and use that control to nap frequently, in a variety of situations even when they do not feel tired. Though replacement nappers also appear to nap frequently, and indicate they have some control over sleep onset, they state that they nap only when they feel tired. It seems likely, therefore, that their naps are in response to increased sleep need.

d. Daytime napping in relation to nocturnal sleep.

(1) Nocturnal sleep characteristics on nap and non-nap days. Our earlier work (Evans & Orne, 1975) had indicated that the primary reason replacement nappers nap is due to their getting less sleep the night before nap days relative to the night before non-nap days ($t=2.10$, $p<.05$). Their truncated sleep appeared to be the result of awakening about 46 minutes earlier on nap days. Interestingly, replacement nappers more often slept less well the night after a non-nap day relative to the night after a nap

day ($t=2.23$, $p<.05$). Appetitive nappers, on the other hand, had no clear differences in nocturnal sleep between nights prior to and following a nap day versus a non-nap day.

We sought to replicate these results, using a 14-day period of our diary data, between laboratory DAYS 3 and 4, since the original findings were based upon a 2-week period. Table 13 contains the mean values

TABLE 13

Mean nocturnal sleep values for nights before nap days (B), after nap days (A), before non-nap days (B-), and after non-nap days (A-), derived from a 14-day period between laboratory DAYS 3 and 4, for 11 appetitive nappers (A), 11 replacement nappers (R), and 9 non-nappers (N).

question	group	nocturnal sleep conditions				within-group comparisons ($p < .05$)*
		B	A	B-	A-	
What time did you fall asleep last night?	A	0205	0206	0206	0154	
	R	0157	0137	0146	0146	
	N	----	----	0232	0232	
Did you sleep well last night? (% yes)	A	89	84	88	87	A > A- (.005)
	R	91	94	88	85	
	N	----	----	74	72	
What time did you wake up this morning?	A	0903	0920	0918	0909	B < B- (.025), B < A (.025)
	R	0832	0858	0910	0904	
	N	----	----	0919	0911	
How long did you sleep last night? (hrs:mins)	A	7:03	7:17	7:21	7:15	B < B- (.01), B < A (.025)
	R	6:36	7:09	7:27	7:18	
	N	----	----	6:50	6:50	

* Wilcoxon matched-pairs signed-ranks tests within each group, between nocturnal conditions. Probability levels are 1-tailed, since significant differences were predicted. Comparisons were not made between conditions B & A-, and B- & A.

for nocturnal sleep onset, offset, length, and quality of sleep for each group, on nights before nap days (B), before non-nap days (B-), after nap days (A), and after non-nap days (A-). Wilcoxon matched-pairs signed-ranks tests between these four conditions within each group revealed a full replication of our original findings.

Replacement nappers slept an average of 51 minutes less on nights

prior to days they napped relative to nights before non-nap days ($p < .01$), and an average of 33 minutes less compared to nights following nap days ($p < .025$). They truncated their pre-nap day nocturnal sleep length by awakening an average of 38 minutes earlier on nap day mornings relative to non-nap day mornings ($p < .025$), and 26 minutes earlier than mornings after nap days ($p < .025$). They also indicated that they slept well an average of 94% of the nights after nap days compared to 85% of the nights following non-nap days ($p < .005$), and they were less likely to recall dreaming after a nap day (48%) relative to nights after a non-nap day (65%; $p < .01$). Appetitive nappers showed no significant differences between conditions, and non-nappers did not have enough nap day data to make comparisons meaningful, though they also did not differ between before and after non-nap days.

Having replicated this important pattern of results for a 2-week diary period, we examined the sleep lengths for the entire 30-day diary to insure the differences in nocturnal sleep were consistent over a longer period of time, as well as to compare sleep lengths between groups. Since the major sleep length differences occurred within replacement nappers on nights before nap days, we examined total sleep time (TST) on nights prior to nap days, TST on nights prior to nap days plus nap durations, and TST on nights prior to non-nap days. Figure 13 depicts the median histograms on these measures for each napper group, and non-nap day TST for non-nappers.

In full agreement with the 2-week data, appetitive nappers had the

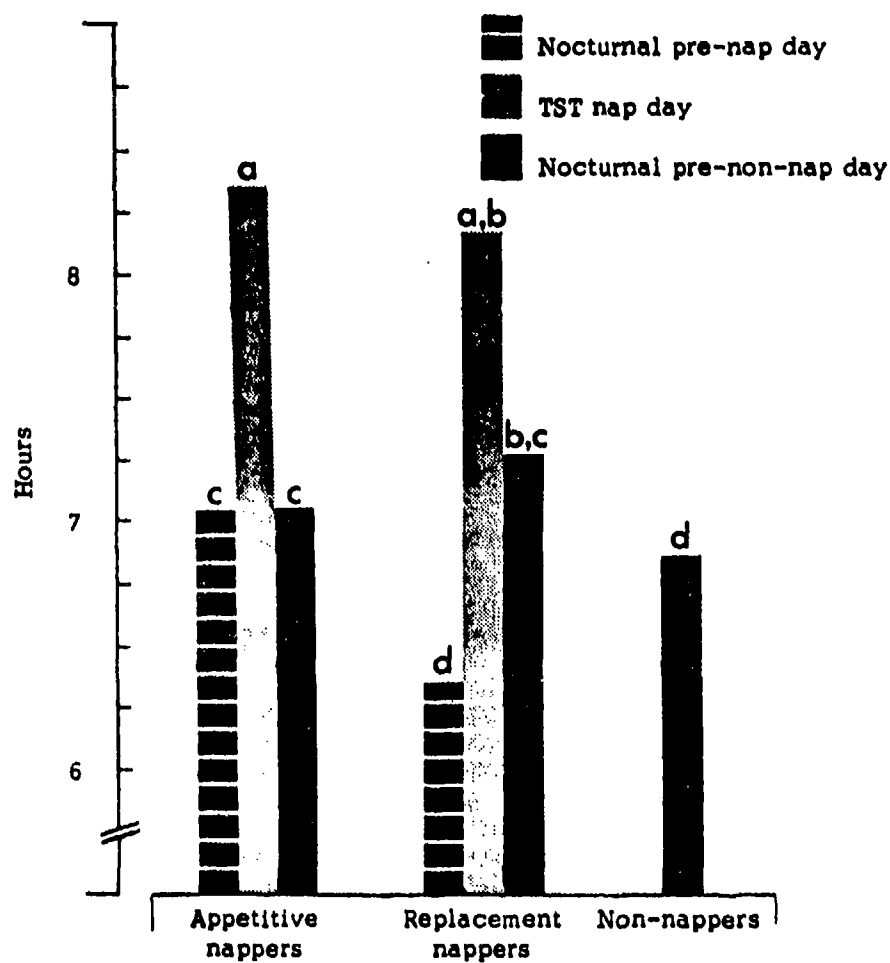


Figure 13. Median sleep lengths for nappers and non-nappers during the 30-day diary period. Histograms sharing the same letter are not significantly different at the $p < .05$ (1-tailed) level or lower, by appropriate non-parametric tests.

same amount of sleep on nights prior to nap days and non-nap days, while replacement nappers had consistently less TST on nights prior to nap days relative to their non-nap day nights ($p < .001$). In addition, appetitive nappers had significantly more nocturnal TST on pre-nap and pre-non-nap nights than replacement nappers did on pre-nap nights ($p < .05$). The only histogram not significantly different from replacement nappers' pre-nap nocturnal TST was non-nappers' pre-non-nap TST, though there was a

trend ($p < .10$, one-tailed) for non-nappers to be higher.

Non-nappers' typical nocturnal sleep length on a non-nap day was significantly below all other TST values for appetitive and replacement nappers. That is, when nappers' nocturnal TSTs prior to non-nap days were compared to non-nappers' TST prior to non-nap days, nappers had consistently higher values (App. $p < .025$; Rep. $p < .01$). Though the differences appear small in Figure 13, non-nappers nevertheless typically slept about 15 to 25 minutes less on nights preceding non-nap days than either napper group. They also slept a few minutes less than appetitives did on pre-nap nights ($p < .05$), and, of course, they had less sleep than either napper group did on nap days, when nap sleep lengths were added to nocturnal sleep ($p < .001$). Consequently, when TST per 24-hour period was assessed across the entire 30-days of the diary, non-nappers had 30 minutes less sleep per day than either appetitive ($p < .001$) or replacement nappers ($p < .05$), while napper groups did not differ.*

In our earlier work, non-nappers also averaged less TST per 24-hours, but did not average significantly less nocturnal sleep than nappers. Nevertheless, when nap and non-nap day nocturnal sleep lengths are compared over a month, non-nappers average consistently less nocturnal sleep prior to their non-nap days than nappers do prior to their non-nap days. Though the difference is well under an hour, it is consistent, and clearly

*This included nap lengths added to nocturnal sleep lengths on nap days. Median values were: non-nappers = 7.14 hrs., appetitive nappers = 7.59 hrs., and replacement nappers = 7.64 hrs. Mann-Whitney U-tests were performed, and significance levels are two-tailed.

indicates that confirmed non-nappers not only get less sleep (relative to nappers) when naps are added to nocturnal sleep time, but, in fact, get less nocturnal sleep than nappers, with the exception of replacement nappers' pre-nap night sleep.*

Further examination of Figure 13 reveals that the highest amounts of sleep obtained understandably occurred when nap lengths were added to nocturnal sleep lengths. Curiously, despite significantly less nocturnal sleep on nap days, replacement nappers had as much TST per nap day as appetitive nappers. This was largely due to replacement nappers' somewhat longer naps (see Table 12), especially on days where the prior night's sleep length was particularly short. Nevertheless, while appetitive nappers' TST per nap day was significantly above all other values, replacement nappers' TST per nap day was not significantly above their TST per non-nap day. This is congruent with our contention that replacement nappers nap in response to fatigue, which appears to be directly a function of acquiring a specific amount of sleep per day. Napping for the replacement napper is a way of balancing the sleep need ledger. Since

*Overall, it appears that subjects participating in the current study slept 30 minutes less per day than subjects who participated in our earlier work. Since the effect appears in all groups, it is possibly the result of a sample difference between our earlier work and the current investigation. One major difference between the studies involved their length. The current study was nearly 4 times as long and demanded much more subject involvement than the original work. Given that all of the current study participants were extremely active curricularly and extracurricularly, in addition to their participation in the study, it is possible that their slightly shorter nocturnal sleep average reflects an even busier activity schedule than participants in the earlier work.

they more often report having slept well following a night after a nap day, relative to a night after a non-nap day (see Table 13), it seems reasonable to suggest that the nap sleep has a positive effect on the post-nap nocturnal sleep (assuming that the replacement napper was not unduly sleep deprived). The mechanism for this is probably little more than the nap sleep adding to the nocturnal sleep which follows it, yielding a TST for the previous 24 hours that is subjectively "enough" sleep.

While the data on nocturnal sleep length presented in Figure 13 was analyzed nonparametrically to avoid making assumptions about data distributions, extensive parametric analyses were also carried out. The parametric analyses fully confirmed the findings, especially the fact that replacement nappers averaged less sleep the night before a nap day versus the night before a non-nap day ($p < .001$) and versus the night before appetitive nappers' nap day ($p < .01$). However, replacement nappers were also significantly more variable (between subjects) in nocturnal sleep duration on pre-nap day nights relative to pre-non-nap day nights ($F_{\max} = 4.72$, $p < .01$), and relative to appetitive nappers' pre-nap day nights ($F_{\max} = 5.19$, $p < .05$). In fact, replacement nappers were more variable in nocturnal sleep length before nap days compared to all other napper and non-napper nocturnal sleep averages. This was primarily due to replacement nappers varying widely in the extent to which they truncated their nocturnal sleep the night before nap days. For example, one individual typically shortened his sleep by nearly 3 hours, while another averaged only 20 minutes less sleep

compared to nights before non-nap days. Thus, while replacement nappers clearly had shorter nocturnal sleep before nap days, the extent to which sleep was truncated varied considerably among individuals.

This is perhaps an appropriate point for discussion of the purpose served by naps for replacement nappers and an emerging view of sleep need. There is a considerable amount of data, primarily the studies of Taub and Berger (1973a, 1973b, 1974a, 1974b, 1976b) that suggest any change in an individual's normal nocturnal sleep schedule, including shortening, lengthening, or displacing nighttime sleep, is likely to have negative effects on the individual's performance and mood. These studies are well designed, the data are consistent, and there is thus little reason to doubt the accuracy of the results.* However, these investigations were carried out on young adults who showed "no daytime napping" (Taub, 1978, p. 39).

While we do not doubt that mood and performance the first day after an altered nocturnal sleep schedule will show adverse effects from the disrupted sleep, we must consider these results in light of the fact that nappers, especially replacement nappers, employ napping during the day to compensate for shortened nocturnal sleep, and thus use naps as an ameliorant for altered nighttime sleep schedules. Nappers might well be the very individuals who could most quickly adapt to such altered schedules, in the sense that they could restore effective functioning by napping to compensate for lost sleep.

*Critical comments (see Webb, 1978b; Hauri, 1979) suggest caution in drawing definitive conclusions from these publications.

The conclusion Taub and Berger, and others, have drawn from their data is that the maintenance of a habitual sleep/wakefulness cycle may be more important for sustaining effective mood and functioning than total sleep time. On the other hand, replacement nappers behave as though getting a set amount of sleep each day is critical for effective functioning, and consequently, while their naps may necessarily alter their sleep/wakefulness cycle, they provide them with the extra sleep required to meet their total sleep need. This is all the more surprising, since they nap in response to relatively small daily fluctuations (30-60 minutes) in nocturnal sleep time.

Nevertheless, replacement nappers' behavior is not necessarily inconsistent with the biorhythmic view Taub and Berger propose. It seems likely that a combination of shortened sleep and a displaced sleep cycle are more debilitating than either factor alone, especially in individuals who do not regularly nap. Replacement nappers comprise a third of our surveyed young adults (see Table 1), and appear to have the capacity to go from a monophasic to a biphasic sleep/wakefulness cycle following nights of reduced sleep, thereby using naps to compensate for some of the lost sleep. Their naps tend to be taken in the afternoon, during a relatively circumscribed period (see Figure 12). Naitoh's (1981) data suggest that afternoon naps are more likely to be beneficial to the sleep-deprived individual than naps at the trough of the circadian activation curve. Indeed, Webb (1978a) has argued that the afternoon nap is the second phase of a naturally-occurring biphasic sleep cycle. It is conceivable that replacement

nappers respond to nocturnal sleep loss by napping during a portion of the circadian cycle highly conducive to permitting the restorative components of sleep to operate.

In contrast, non-nappers are either unaccustomed to using this second phase to sustain functioning (i.e., can't fall asleep), and thus need time to adjust, or they may be unable to derive any benefits from the second phase, as is the case with our confirmed non-nappers.

Appetitive nappers appear to have the most consistent biphasic sleep/wakefulness cycle, and their napping may be the closest to an univocal biorhythmic pattern. Their nocturnal sleep does not differ on nights before nap days compared to nights before non-nap days, they report being able to go to sleep in a variety of situations, they indicate the highest preference for a few short naps relative to one long sleep period, they can fall asleep in a non-optimal environment in the afternoon without being sleep deprived, and they nap more frequently in the afternoon than other groups. Moreover, they have no sleep problems, no obviously peculiar personality characteristics, or unique behavioral activity patterns.

Further evidence for the biorhythmic nature of appetitive nappers' naps comes from their circadian functions for subjective activation (see Figure 11). They were the only group to reveal clear differences in ratings of general activation and deactivation-sleep, in the afternoon, between nap and non-nap days. Days on which they do not engage in napping (a monophasic sleep cycle) are distinguished by more general activation and an extreme lack of sleepiness. While the characteristics of their non-nap

days, particularly those aspects that lead to minimal sleepiness, remain uncertain, it is apparent that if asked to nap on such days, as in DAY 3 of the current study, they can do so. From a biorhythmic perspective, appetitive nappers appear to possess the ability to sleep biphasically, and do so frequently, but certain days are distinguished by little sleepiness, and a decision not to nap.

(2) Nocturnal sleep before and after laboratory naps. An analysis of characteristic sleep patterns on nap versus non-nap days was not only possible for the entire diary period, but was also completed for nights before and after laboratory nap sessions. Since the laboratory sessions were known nap periods, nocturnal sleep prior to and following them should reflect both subjects' need to nap as well as the consequences of their naps on the subsequent night's sleep.

Figure 14 presents the median sleep lengths for nights before all four laboratory sessions, as well as for pre-nap and pre-non-nap nights from the entire 30-day diary. Significant differences within each group are indicated in the figure. As expected, appetitive nappers had no consistent differences among any of their sleep lengths, again illustrating that their nocturnal sleep is unrelated to their daytime napping.

Replacement nappers, as was noted above, had significantly less sleep on nights prior to nap days relative to pre-non-nap days. In addition, however, they also had less sleep the night before the DAY 3 laboratory nap (in the sleep hostile environment) relative to their typical pre-nap day nocturnal sleep ($p < .05$), and their sleep the night before wake control DAY 4

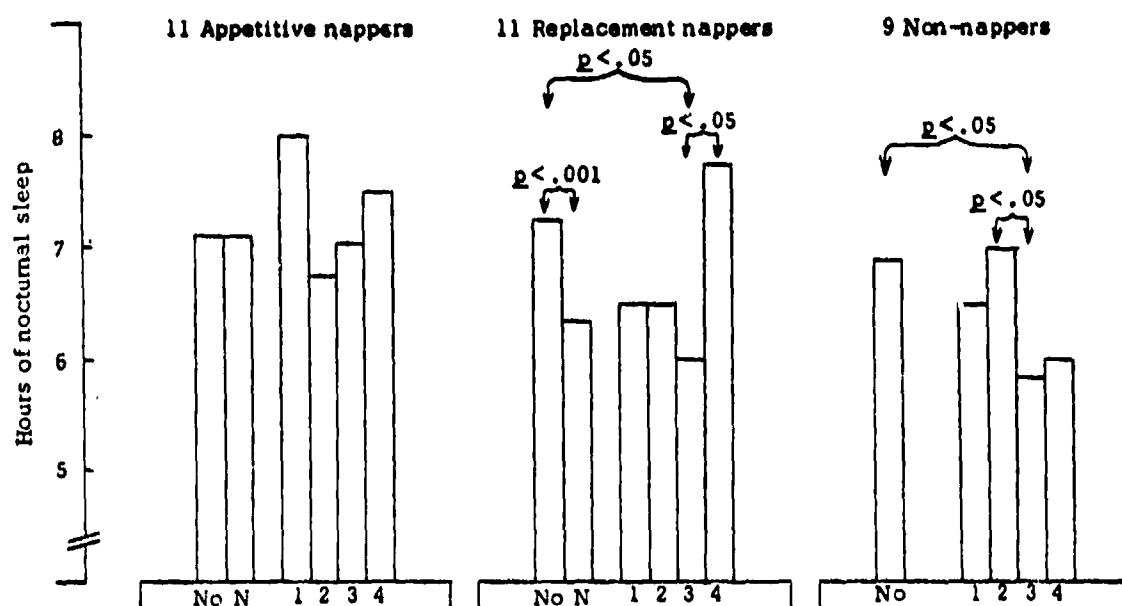


Figure 14. Median values for nocturnal sleep lengths on nights before nap days (N), nights before non-nap days (No), and nights before the 4 laboratory sessions: control DAYS (1 & 4), and nap days (2 & 3). Nap and non-nap values are from the 30-day diary records. Wilcoxon matched-pairs signed-ranks tests were carried out between histograms within each group. Significance levels are two-tailed.

($p < .05$), when they knew that they would not be napping. In general, their median sleep length for nights prior to the first three laboratory visits, when they expected to nap, were very similar to their typical night sleep length prior to nap days, that is, somewhat truncated. Apparently, asking a replacement napper to nap, particularly in an alerting environment, and simultaneously asking him to get a "normal" night's sleep, results in the individual getting nocturnal sleep of the same duration as a typical pre-nap night. This, after all, is what occurs "normally" for replacement nappers on pre-nap day nights. This suggests that they control their nocturnal-sleep/nap-sleep pattern such that they may choose to get less sleep one night by getting up earlier, knowing that they can compensate the partial sleep loss by napping later in the day.

Non-nappers showed what we consider to be the most surprising pattern in Figure 14. Their nocturnal sleep lengths the night before nap DAY 3 (the alerting environment) were significantly below their typical pre-non-nap day nocturnal values ($p < .05$) and below their pre-nap DAY 2 nocturnal values ($p < .05$). They received less sleep the night before nap DAY 3 by going to bed significantly later (around 3:45 a.m.) relative to their usual bedtime (2:05 a.m.). This may account for why only 5 non-nappers were able to fall asleep in the optimal nap environment of DAY 2, while 7 of the 9 were able to sleep in the alerting environment of DAY 3. Like replacement nappers, they tended to increase the likelihood that they would sleep in the alerting environment by partially sleep-depriving themselves the night before. In a sense, they were responding adaptively to the demands of the situation, namely to nap in a setting designed to be uncondusive to sleep.

Non-nappers not only slept less the night before nap DAY 3 relative to nap DAY 2, but they also slept significantly more the night of DAY 3 (following the nap) than the night following the DAY 2 nap ($T=0$, $p < .035$). This would suggest that the nap in the alerting environment of DAY 3 did not replace the partial loss of nocturnal sleep from the night before, and this is consistent with the fact that non-nappers reported the DAY 3 nap to be very unsatisfying, and not at all refreshing (see Table 7). Nappers, on the other hand, generally reported positive effects from the nap in the alerting environment, and did not sleep more following DAY 3 nap, though replacement nappers reported falling asleep faster ($T=3$, $p < .025$).

the night after the DAY 3 nap (Mdn=5 mins.) relative to the night after DAY 2 (Mdn=15 mins.). This may indicate that the replacement nappers also benefited somewhat less from the DAY 3 nap than from the DAY 2 nap. Laboratory naps did not appear to have differential effects on appetitive nappers' post-nap nocturnal sleep.

(3) Sleepiness and fatigue on nap and non-nap days. In addition to the subjective activation checklists used to assess circadian variation in sleepiness and fatigue on nap days relative to non-nap days, the sleep diary contained a series of questions concerning how much (and when) an individual felt tired each day. By pooling within and between subjects, it was possible to assess fatigue on nap days relative to non-nap days. (Parametric analyses were used on these data because a large number of tied responses precluded appropriate nonparametric tests.) Major comparisons (ANOVAs) consisted of appetitive and replacement nappers (2 groups) compared across nap and non-nap days (2 trials).

If appetitive nappers generally nap for reasons unrelated to fatigue, as was suggested in our original hypothesis and confirmed by nocturnal sleep lengths, then they would likely show no difference in fatigue on nap days relative to non-nap days, while replacement nappers should clearly be more tired, and tired sooner on nap days compared to non-nap days. Table 14 contains the mean nap and non-nap day sleepiness responses during the 30-days of the diary for both napper groups as well as the ANOVA results for each response. The persistent lack of a significant interaction F ratio for any of the questions indicates that contrary to our

TABLE 14

Mean sleep diary sleepiness responses for nap days and non-nap days of appetitive nappers (n=11) and replacement nappers (n=11). Two-way repeated measures ANOVA F ratios are presented.

Sleep Diary Question	Appetitive Nappers		Replacement Nappers		Days ¹	Groups ²	Inter. ³
	nap day	non-nap day	nap day	non-nap day	$F_{1,20}$	$F_{1,20}$	$F_{1,20}$
Time you felt most tired?	3:41 pm	5:58 pm	5:34 pm	6:56 pm	10.97**	5.10*	0.68
Were you fighting off sleep at any time? (Y=1, N=0)	0.31	0.17	0.41	0.20	15.47**	1.19	0.65
Time you were fighting off sleep?	4:59 pm	5:48 pm	4:43 pm	7:13 pm	5.24*	0.23	1.30
Were you so tired you had difficulty concentrating?	0.25	0.14	0.30	0.15	8.19**	0.21	0.18
How sleepy are you? (1=wide awake, 10=extremely sleepy)	4.25	4.17	5.33	4.94	9.99**	2.49	0.02
Could you sleep now if you had the time? (Y=1, N=0)	0.68	0.58	0.65	0.56	8.80**	0.03	0.01

¹ Main effect within subjects (nap days versus non-nap days).

² Main effect between subjects (appetitive versus replacement).

³ Interaction ratio.

* $p < .05$

** $p < .01$ or lower.

expectation, appetitive and replacement nappers did not report different degrees of fatigue on nap days. The only between groups difference was for time of day subjects felt most tired, where appetitive nappers reported being most tired earlier in the day (especially nap days) than replacement nappers. It is interesting that the mean time appetitive nappers indicated they were most tired on nap days (3:41 p.m.) coincided with the time they most frequently napped (see Figure 12; mode=1500-1600).

The most consistent finding in this sleep diary sleepiness data was the main effect due to days. On nap days, nappers -- regardless of group -- reported feeling tired earlier, were more likely to be fighting off sleep, were fighting off sleep earlier, and were more likely to be so tired that concentration became difficult, relative to non-nap days. At the end of

diary completion on the morning of a nap day, they also indicated greater sleepiness than on non-nap days, and were more likely to say they could sleep now if they had the time. Non-nappers are not presented in Table 14, but their non-nap day mean values were similar to nappers' non-nap days, though non-nappers were generally more variable in their responses to these questions.

The data presented in Table 14 suggest that nappers' subjective impressions (if not also their actual experiences) vary as a function of whether a day contains a nap or not. In particular, impressions of fatigue seem more pronounced and are perceived to be earlier on nap days. Of course, this may simply reflect nappers' desire to justify having taken a nap. That is, recalling that he napped yesterday (and when) may suggest to the napper that he must have been tired then. Nevertheless, being tired earlier on a nap day (and fighting off sleep earlier) is consistent with subjective activation circadian data that show both napper groups experiencing a significant drop in general activation from noon to 4:00 p.m. on nap days, but not on non-nap days (see Table 9).

While replacement nappers' nap day fatigue is readily understood when one considers their typically truncated sleep the night before a nap day, appetitive nappers' nap day fatigue is not accounted for by either the quantity or the quality of the previous night's sleep. Indeed, appetitive nappers were selected because they reported napping even when they did not feel tired. This clearly suggests what a variety of laboratory and extra-laboratory data confirm, namely, that appetitive nappers have a

remarkable degree of control over when they sleep. On the other hand, the subjective data indicate that, like replacement nappers, they are reporting less activation and more tiredness and sleepiness earlier in the afternoon on nap days. They appear to be more fatigued on nap days. This subjective data could reflect a number of processes occurring on appetitive nappers' nap days:

(1) On a day they choose to nap, appetitive nappers might prepare themselves by lowering their activation, much the way nappers appeared to have lowered both physiological and subjective activation prior to the laboratory naps (see Figures 5 and 10). Seen in this way, the lowered subjective ratings reflect a preparation for napping that stems from a control over their ability to nap. Such a view should predict that appetitive nappers nap without clear sleep need (though they may replacement nap when required).

(2) On the other hand, on nap days appetitive nappers show lowered activation and increased sleepiness. The possibility must be considered that this subjective experience reflects a sleep need. The appetitive napper may still have control over whether he naps, but there is increased impetus to nap. This impetus may result from needing additional sleep and/or this sleep need may be related to a biphasic sleep cycle. However, no diary data indicated that appetitive nappers have increased sleep need, at least not in terms of their nocturnal sleep/wakefulness patterns.

To examine these alternatives, another approach to the question

of sleep need in appetitive nappers was necessary.

e. Sleep desired versus sleep obtained. While the diary data indicated that appetitive nappers did not consistently nap as a result of reduced nocturnal sleep, it was not possible to determine precisely why appetitive nappers napped so frequently. They may simply require more sleep to feel at full capacity, and they gain the desired amount by supplementing their nocturnal sleep with daytime naps. One way to address this issue is to compare the sleep lengths subjects report they desire to what they actually average.

At the beginning of the experiment we asked subjects to complete a questionnaire that included, among other things, the following questions: "During the past year, how many hours of sleep have you regularly had per night? How many hours of sleep do you need per night? How many hours of sleep per night would you like to get?" Thus, we had individuals' estimates of their typical nocturnal sleep, the amount of sleep they perceive themselves as needing, and the nocturnal sleep they would ideally prefer to get.

While all groups indicated that they had been getting roughly the amount of nocturnal sleep they needed, they also indicated that they would have liked more sleep than they estimated that they had been getting nocturnally. This was especially true for replacement nappers ($t=4.55$, $p<.001$), but less so for appetitive nappers ($t=1.91$, $p<.10$) and non-nappers ($t=1.84$, $p<.11$).^{*} Replacement nappers were the only group who also indicated

^{*}Student t -tests for paired comparisons were used for the analyses in this section, since a large number of responses to the questions were tied, making nonparametric analyses more difficult. All significance levels reported here are two-tailed.

they would like significantly more nocturnal sleep than they needed ($t=3.61$, $p < .01$). When comparisons were made between groups on these questions, no significant differences emerged, a result consistent with questionnaire data from our earlier study (Evans & Orne, 1975).

What interested us most about these data were how they related to the actual sleep diary averages for TST on nap and non-nap days. The operational definition of sleep need we employed when analyzing the diary data was the amount of nocturnal sleep individuals had on nights prior to non-nap days. These questionnaire responses, however, provided another way to address sleep need in relation to daytime napping. Consequently, we compared the questionnaire responses to the following five 30-day diary parameters: TST on non-nap days, TST on nights before nap days, TST on nap days (nocturnal + nap time), nocturnal TST for the entire 30 days, and TST per 24-hour period for the entire 30 days.

Thirty-eight of 72 comparisons were significant at $p < .05$ (two-tailed) or lower, a result well beyond ($p < .001$) what chance would allow (Sakoda, Cohen, & Beall, 1954). Replacement nappers, as expected, were the only group who averaged less sleep on nights before nap days than they indicated they typically had during the past year ($p < .02$), confirming that a night of truncated sleep prior to a nap day is not a typical replacement napper night. All three groups indicated they would like more nocturnal sleep than the diary revealed they received on pre-nap day nights ($p < .002$ to $p < .0001$), or pre-non-nap day nights ($p < .01$ to

$p < .002$), nocturnally for the entire 30 days ($p < .02$ to $p < .0002$), and TST per 24-hour period for the entire 30 days ($p < .02$). The only diary category that was not significantly different from what subjects said they would like was TST on nap days. In terms of sleep need, all three groups received less sleep on pre-nap day nights than they viewed themselves as needing ($p < .02$ to $p < .001$), and only appetitive nappers claimed to have needed significantly more sleep than they received on pre-non-nap day nights ($p < .05$), as well as nocturnally throughout the entire 30 days ($p < .02$).

This last result suggests that appetitive nappers may indeed nap as a supplement to their perceived sleep need. They estimated their nocturnal sleep need, and yet all of their nocturnal diary averages were unequivocally below their estimated need. Viewed this way, appetitive nappers' frequent daytime naps appear to be not only a second component of their sleep cycle, but, when added to TST from the night before, the naps help supplement the requisite amount of sleep these individuals view themselves as needing. While replacement nappers normally fulfill their perceived sleep need with nocturnal sleep, and thus nap only when nocturnal sleep is too short, appetitive nappers apparently rarely fulfill their perceived sleep need nocturnally, and, as a result, typically take daytime naps to satisfy this need. Ironically, they do not perceive themselves as napping because they are tired, though their subjective reports indicate they are more sleepy and less energetic on nap days. They appear to nap because afternoon sleep is not only possible, but desirable and pleasant. Their perceived sleep need is met by a natural biphasic sleep/wakefulness pattern.

TST on nap days not only satisfied individuals' estimated sleep needs, but also came closest to providing subjects, including non-nappers, with the amount of sleep they would like to get each night. Since all groups showed this effect, we pooled subjects and present the resulting paired-t values in Table 15. Examination of the table confirms that

TABLE 15

Paired t-test values for comparisons between mean subjective sleep length estimates and diary sleep lengths for all 31 subjects (11 appetitive nappers, 11 replacement nappers, and 9 non-nappers).

		TST no-nap days	nights before nap days	TST nap days	night mean all 30 days	TST all 30 days
Subjective estimate	Mean (sd)	7.23 (0.58)	6.57 (0.93)	7.86 (0.99)	7.06 (0.57)	7.48 (0.64)
Nocturnal sleep you <u>had</u> in past year?	7.44 (1.06)	1.14	4.70**	-2.18	2.36	-0.26
Nocturnal sleep you <u>used</u> ?	7.74 (1.12)	2.50	6.14**	-0.60	3.58*	1.39
Nocturnal sleep you <u>would like</u> to get?	8.35 (0.94)	6.54**	9.44**	2.26	7.74**	5.04**

* $p < .0006$ (two-tailed) -- to maintain $p < .05$ when 72 tests carried out.

** $p < .0001$

although subjects generally received the amount of nocturnal sleep they claimed they had in the past year, nights prior to nap days were the exception. This was largely evident among replacement nappers and non-nappers. Similarly, in terms of nocturnal sleep need estimates, pre-nap day nights were lower, as was the 30-day nocturnal average. The latter was primarily due to appetitive nappers. When estimates of the nocturnal sleep length subjects would like were compared to diary data, all nocturnal averages and the TST per 24-hour period for all 30 days were well below

the estimated amount desired. Only TST on nap days satisfied what subjects would like.

Since non-nappers very rarely nap, they virtually never get as much sleep as they would like. Nappers, on the other hand, especially appetitive nappers, frequently obtain the amount of sleep they would like by napping during the day. Though both appetitive and replacement nappers use napping to obtain their perceived sleep need, the primary difference would appear to be that whereas replacement nappers nap to complement a sleep need that is normally fulfilled nocturnally, appetitive nappers nap to satisfy a sleep need that is not only not satisfied at night, but may be tied to a natural biphasic sleep/wakefulness cycle.

E. Discussion.

1. Napping, Sleep Need, and Sleep Cycle.

A major goal of our work has been to determine the functions and consequences of napping through an investigation of individual differences in napping behavior. The original conceptualizations we had of the functions served by brief daytime sleep incorporated both of the two major theoretical approaches to the functions of sleep in general. Replacement nappers were thought to nap due to increased sleep need (only when tired), and diary evidence for an association between the likelihood of their napping and truncated sleep the night before appears to provide a significant confirmation of this view. However, appetitive nappers were thought to nap for reasons unrelated to sleep need (even when not tired), and their diary data support the view that they have increased control over sleep and at least an intermittent biphasic sleep cycle not obviously tied to nocturnal sleep length.

Appetitive nappers not only napped more than replacement nappers, but they also averaged more nocturnal sleep than non-nappers. While the difference in each case is relatively small, appetitive nappers consistently appeared to get more sleep, particularly relative to non-nappers. This is especially obvious when one considers total sleep time (TST) per 24-hour period. Given the greater TST among appetitive nappers, is it appropriate to conclude that they need more sleep? As Rechtschaffen (1979) pointed out, "Some subjects or groups might sleep much not because they need it most but because they have the best developed or

functioning mechanisms for getting it. They may be the subjects who need sleep the least." (p. 11).

Indeed, there is compelling evidence that appetitive nappers are remarkably adept at getting sleep. They not only nap frequently without shortened sleep the night before, but they also report being able to fall asleep almost anywhere, and they do not have to be tired to nap, as is evidenced by both the questionnaire data as well as their ability to fall asleep in the alerting environment of nap DAY 3 despite self-reports of little fatigue or sleepiness. On the other hand, their sleep need estimates suggest they also feel they need more sleep than replacement nappers and non-nappers, since they were the only group with need estimates significantly above average nocturnal TST.

It is, of course, possible that appetitive nappers estimate they need more sleep because they get more sleep, rather than their acquired sleep following from their estimated need. The same criticism might be made for replacement nappers' estimates. However, this does not explain why their estimates coincided with sleep length on nights prior to non-nap days, and with TST on nap days (nocturnal + nap), but not with sleep length on nights prior to nap days. Presumably their sleep need was not met on certain nights, thereby creating a sleep debt, which was reflected in feelings of tiredness the next day and a propensity to nap. Such speculation has clear recovery or restorative overtones, by positing that reduced nocturnal sleep was the cause for napping.

It is possible to reject this interpretation by arguing as Webb (1978a)

has "that the sleep debt does not bring about the nap, but the nap is simply a sensitized response to the biological rhythm tendency to sleep during the 'nap time'." (p. 316). If so, it remains to determine what the mechanism is for sensitizing the biorhythmic tendency to sleep. For replacement nappers, this sensitizing results from a relatively small reduction (30-60 mins.) of nighttime sleep. However, if a modest loss of nocturnal sleep increases the probability of subsequent daytime napping by sensitizing a biorhythmic tendency, then maintenance of TST appears to reflect a sleep need that may be intimately tied to the timing of the sleep/wakefulness cycle.

In terms of behavioral adaptation, replacement nappers would rather change a monophasic sleep cycle to a biphasic cycle than to miss what they perceive to be needed sleep. Apparently they feel they can function more effectively and feel better if they nap and derive the needed amount of sleep per 24-hour period. The benefits of acquiring the desired TST appear to outweigh the consequences of altering the sleep/wakefulness cycle.

On the surface this seems to be contrary to Taub and Berger's (1973a, 1973b, 1974a, 1974b, 1976b) conclusions that disruption in the timing of the typical monophasic sleep/wakefulness cycle may be more detrimental to performance than partial reductions in TST. However, since the Taub and Berger studies were carried out on habitual non-nappers, their conclusions may apply more to this group than to habitual nappers.* An individual difference

*Since numerous studies have now documented that habitual nappers (1/wk.) make up over 50% of the young adult college population (see Table 1), and that their napping is generally not the result of any chronic nocturnal sleep problem, the Taub and Berger findings may not be generalizable to a significant portion of the population. This is important since they are rather widely touted as definitive proof that small manipulations of circadian rhythms are much more disruptive to mood and performance than modest amounts of sleep deprivation (e.g., Rechtschaffen, 1979).

explanation would also account for why Knowles et al. (1978) were unable to replicate the Taub and Berger findings on a randomly selected group of subjects. In addition, Taub and his associates appear to provide support for such an explanation by showing that habitual nappers benefit from morning naps nearly as much as evening naps, despite the 180° phase difference between them and the varied sleep stage infrastructure (Taub et al., 1978). We conclude that while acute alterations in the monophasic sleep of subjects are likely to have some negative consequences, and though these consequences may be independent of TST, some individuals appear to be able to adapt to these effects more readily than others, particularly when the biorhythmic effects shorten TST. The adaptation takes the form of napping, that is going from a monophasic to a biphasic sleep cycle, which concomitantly adds to TST.

Though morning and evening naps have benefits for habitual nappers, the biorhythmic constraints on napping are clearly evidenced by the tendency for naps to naturally occur in the afternoon during the middle of the typical wakefulness period (Figure 12). Webb (1978a) has argued that if sleep serves a restorative function, the tendency to nap should be cumulative across the waking period rather than time-bound to the waking midpoint. That is, prior wakefulness should create increasing pressure for sleep, assuming sleep compensates for some as yet unidentified physiological process during wakefulness. Thus, the timing of naps in habitual nappers appears to support a biorhythmic interpretation of nap function, though the relationship between naps and TST in nappers, especially replacement

nappers, suggests a restorative function as well.

It is conceivable that sleep need may motivate habitual nappers to nap while biorhythmic constraints determine when the nap is most likely to be possible, as well as beneficial to both subsequent waking function and subsequent sleep. Individual differences in these biorhythmic constraints and sleep need account for confirmed non-nappers' difficulties falling asleep in the afternoon, or deriving benefits when they do nap. For nappers, naps at any time of the day may be beneficial by providing the desired TST per 24-hour period. However, afternoon naps may be more adaptive from the perspective of enhancing waking functioning without adversely affecting subsequent nocturnal sleep or the typical sleep/wakefulness cycle. They may even serve to facilitate subsequent nocturnal sleep. For example, replacement nappers more frequently felt they slept better on nights following nap days relative to nights following non-nap days.

We are suggesting that the benefits of brief sleep periods will vary as a function of three factors: (1) the amount of sleep pressure which is related to the duration of prior wakefulness and the amount of prior sleep, (2) the portion of the biorhythmic cycle during which sleep is obtained, and (3) individual differences in perceived sleep need, the ability to control sleep onset, and the habitual sleep/wakefulness cycle.

For non-sleep-deprived subjects our data, as well as that of Taub and his colleagues (e.g., Taub & Berger, 1976b; Taub et al., 1976; Taub et al., 1978) and Bartelson (1979), support the importance of individual

differences in sleep/wakefulness patterns, particularly napping versus non-napping, when predicting responses to brief sleep periods. On the other hand, sleep need and biorhythmic factors may become even more critical and override individual differences in situations involving sleep deprivation.

Naitoh's (1981) study on the effects of 2-hour naps at the trough of the circadian cycle and in the afternoon in sleep-deprived sailors revealed that a nap between 0400 and 0600 had negative effects on performance and mood, while an afternoon nap (1200-1400) had significant recuperative effects on both, and one afternoon nap following 53 hours of wakefulness was as recuperative as a combination of an early-morning nap and a mid-day nap after 45 hours of wakefulness. Naitoh suggested that the poor performance and mood he observed following his sleep-deprived subjects' early-morning nap was due to prolonged prior wakefulness increasing the duration of negative post-sleep effects typically found at this time of day. This seems to indicate that biorhythmic determinants interacted with the effects of increased sleep need. The same mechanism may in part account for Hartley's (1974) finding that three 80-minute naps a day maintain vigilance functioning better than one 4-hour sleep period a day. While he attributed the superior performance in the distributed sleep (nap) group to reduced wakefulness prior to testing, it is noteworthy that the 4-hour continuous sleep group slept "at the lowest point of the diurnal cycle." (Hartley, 1974, p. 9).

The similarity between the Hartley (1974) and Naitoh (1981) studies

is that the reduced sleep period that was least effective for improving functioning was the one taken at the trough of the circadian cycle after sleep need had increased by either partial or total sleep deprivation. Though it is uncertain how individual differences may have affected the results of these studies, it seems clear that they illustrated the relevance of biorhythmic parameters when predicting the value of short sleep periods for individuals with increased sleep need. Moreover, they are in accord with both laboratory (Lubin et al., 1976) and field studies (Haslam, 1981) showing the value of a few short naps for recovering or sustaining functioning in young adults otherwise deprived of sleep.

While there seems to be little doubt that napping is better than no sleep at all, it is somewhat less certain how napping can be most efficiently employed by individuals restricted in sleep length and opportunity. From the perspective of maintaining effective functioning during quasi-continuous operations, we have proposed using napping prophylactically to ward off the deleterious effects of sleep-deprivation, that is, prior to profound sleep need developing. As we have seen above, this would necessarily require taking into account individual differences in sleep need, frequency of napping, ability to nap, and responses to naps; and recognizing that there may be periods of the day, especially during the circadian trough, when napping may be counterproductive. Before napping regimes can be applied to problems of sustained operations, it is important to discuss the mechanisms that may be indicative of control over napping, the full negative and positive consequences of napping, and the

degree to which these vary as a function of individual differences and environmental circumstances.

2. The Consequences of Napping.

Feelings of sleepiness and/or fatigue are the most consistent precursors of sleep, and though it is uncertain whether they are causal to sleep, part of sleep, or related via another mechanism (Rechtschaffen, 1971, 1979), it is common to find that they are also the parameters most changed following sleep. This appears to be equally true for daytime napping. Following the laboratory naps, nappers reported being less sleepy, less tired, less deactivated, and more energetic relative to before the naps and after wake control periods. They also expressed satisfaction with the naps, indicated they were refreshing, and felt better relative to before them. Their mood was clearly more positive and this appears to be the most consistent finding among studies of habitual nappers (Taub et al., 1976; Bertelson, 1979). In contrast, and as expected, confirmed non-nappers revealed no change in sleepiness or tiredness ratings, and actually reported feeling worse after the naps than before them.*

Changing the nap environment from an optimal one to a non-optimal one produced somewhat less positive mood post-nap in nappers, especially appetitive nappers, though the effect was very modest. Nappers basically

*To our knowledge, our laboratory's program is the first to report the effects of daytime naps on habitual non-nappers. However, it must be kept in mind that the non-nappers we chose to study were a select small percentage of non-nappers who specifically avoided napping because it produced unpleasant consequences for them. Their mood following the laboratory naps clearly validates the selection criteria. There are many non-nappers who do not report naps as unpleasant, and consequently it is not certain how they would respond to napping.

reported feeling better after the naps, and the slightly smaller degree of subjective benefit following the nap in the alerting environment was likely related to the increased disturbance of sleep during the nap. This took the form of greater sleep stage lability and increased transient fluctuations to wakefulness. The fluctuations were so brief (15 sec.) that TST was no shorter than DAY 2, but stage 1 was significantly increased at the expense of stage 4 sleep, a result also noted in the Ichihara et al. (1979) investigation of napping in a chair. Consequently, while non-sleep-deprived nappers were able to sleep in an alerting nap environment, the added stimulation from that environment markedly changed the infrastructure of nap sleep without significantly attenuating the positive mood increases the nap provided for habitual nappers. This suggests napping is not only possible, but potentially beneficial in less than ideal circumstances, though, of course, extremely hostile surroundings could make sleep more difficult.

While all subjects' nap sleep was affected by the alerting environment, confirmed non-nappers were most affected. Despite a similar TST, they averaged 61% less stage 4 sleep and 43% more stage 1 sleep, due to twice as many transient awakenings in the alerting environment. The magnitude of these nap sleep infrastructure alterations was primarily the result of non-nappers having a large proportion of their nap in the optimal environment in a deep, highly consolidated sleep. This seems to confirm what we had originally hypothesized to be the basis underlying confirmed non-nappers' reports of naps having negative consequences. That is, it appears that when they nap, particularly in surroundings similar to nighttime

sleep, they display a sleep morphology reminiscent of early nocturnal NREM sleep. It may well be that waking confirmed non-nappers from an afternoon nap is analogous to waking someone after the first hour of nocturnal sleep -- an experience most of us would likely describe as unpleasant. Such an interpretation is not inconsistent with Taub's (1977) suggestion that non-nappers would find naps unpleasant because napping would alter their typical sleep/wakefulness cycle. We are suggesting that the alteration actually involves the onset of a nocturnal sleep pattern in the afternoon.

How then do nappers, especially non-sleep-deprived nappers, adapt their nap sleep to avoid the highly consolidated sleep pattern of non-nappers? The answer appears to be that they have more transient light sleep during their naps in a sleep-conducive environment. Appetitive nappers napped most frequently and typically had the highest number of transient sleep stage changes and stage 1 epochs, as well as the largest amount of stage 1 sleep. In both our earlier work (Evans et al., 1977) and DAY 2 of the current study, they were significantly above confirmed non-nappers in these parameters, with replacement nappers in between the two groups.* This is an intriguing finding, and though a firm conclusion regarding

*Both Taub et al. (1976) and Bertelson (1979) have reported even higher proportions of light sleep during naps by habitual nappers, and Lawrence (1971) has remarked on the profound individual differences on this parameter. Bertelson (1979) reports the only study outside our laboratory that compared appetitive nappers' and replacement nappers' nap sleep infrastructure. She found a nonsignificant trend for appetitive nappers to have more stage 1 sleep ($t=1.3$, $df=18$, $p<.10$). In our earlier study (Evans & Orne, 1975), we noted significantly more stage 1 sleep in appetitive nappers relative to replacement nappers. While in our current study appetitive nappers also have more light sleep, the difference was not significant.

the significance of it is not possible, it is not difficult to speculate on a potential function for nappers' typical nap sleep infrastructure.

Afternoon napping in habitual nappers appears not to interfere with subsequent nocturnal sleep quality. However, there is some evidence that slow wave sleep (SWS) obtained during late afternoon naps (4-6 p.m.) reduces the amount of SWS during the subsequent night's sleep (Karacan, Williams, Finley, & Hirsch, 1970). For habitual nappers, it might be highly adaptive to nap in such a way as not to disturb subsequent nocturnal sleep in terms of reduced SWS or alteration of a process concomitant with SWS, such as growth hormone release (Takahashi, 1979). Naps comprised of fluctuations to fleeting wakefulness and light sleep would minimize the amount of SWS. Increased light sleep would also contribute less to the immediate post-nap performance decrement, and allow nappers to engage in environmental monitoring to facilitate spontaneous awakening from naps (though little is known about the awakening process). To further understand the relevance of nap sleep infrastructure for the consequences of napping, studies of nocturnal sleep before and after naps by habitual nappers and confirmed non-nappers would have to be completed.

We have suggested that nap sleep infrastructure may have some relevance for confirmed non-nappers' post-nap attitudes toward the nap. Generally, studies of habitual nappers have not, however, supported the existence of any meaningful relationship between nap sleep staging or length, and post-nap waking function (Taub et al., 1976; Taub et al., 1978; Taub & Tanguay, 1977). While our habitual nappers' data are consistent

with this, we would qualify the statement by noting it is true as long as one assesses mood and performance 15 minutes or more after the nap, to avoid acute "sleep inertia" (Lubin et al., 1976).

Immediately after a nap both mood and performance are somewhat depressed, and these post-nap decrements appear to be associated with different aspects of nap sleep infrastructure. For example, the majority of subjective benefits from naps were most evident 40-60 minutes post-nap compared to 6-10 minutes post-nap (Table 8). Similarly, post-nap reaction time (RT) performance was slower out of sleep than wakefulness, and the deeper the sleep stage, the slower the RT (Figure 7A), a result well-documented in the literature (Goodenough et al., 1965; Okuma et al., 1966; Scott & Snyder, 1968; Webb & Agnew, 1964). Most interesting, however, was the relationship between the immediate post-nap decrement in complex cognitive performance and TST during the naps (see Dinges et al., 1981). The longer the sleep the greater the immediate cognitive decrement (Figure 7B).

This is not only the first demonstration of a cognitive performance decrement following afternoon naps, but is the first study to report a relationship between the degree of decrement and TST, rather than sleep stage at nap termination. To our surprise, the cognitive decrement was largely unaffected by either an alerting nap environment or a very loud waking bell, and this is congruent with a conclusion from a series of nocturnal post-sleep decrement studies (Hartman, Storm, Vanderveen, Vanderveen, Hale & Bollinger, 1974). Given the number of tasks that have shown post-sleep decrements, it seems reasonable to conclude that the immediate effects of

sleep on waking performance are negative, even if the sleep is a relatively brief daytime nap by a non-sleep-deprived habitual napper in an alerting environment.

Since the decrements appear to be partly a function of the depth of sleep (via sleep stage or TST), it is entirely likely that they would be even more severe following naps by sleep-deprived individuals (Naitoh, 1981), or sleep periods during the circadian trough (Fort & Mills, 1972), or both (Naitoh, 1981). Consequently, though they are transient, they pose a potential risk for individuals sleeping during sustained operations, particularly if those individuals have been sleep-deprived. On the other hand, anecdotal reports suggest that pre-sleep sets, motivational factors, and a variety of alerting behaviors may serve to modify the decrements. If Naitoh (1981) is correct in concluding that the decrement can last for hours after a nap by sleep-deprived individuals (during the trough of the circadian cycle), then more work is clearly needed on the factors affecting the duration, intensity, and modification of the post-nap performance decrement.

Though functioning appears to be impaired immediately after a nap, it is typical for performance to recover to or above pre-nap levels within 30 minutes of an afternoon nap, depending upon the task, pre-sleep conditions, and the individual. Thus, the greater the post-nap cognitive decrement we observed, the greater the subsequent improvement in performance. Some performance, particularly RT, is reported to be significantly above pre-nap levels following naps by non-sleep-deprived habitual nappers

(Taub, 1977), though Bertelson (1979) could not replicate the result. In sleep-deprived subjects nearly every type of performance affected by sleep deprivation has been shown to improve above pre-sleep levels following naps (e.g., Lubin et al., 1976; Obstad et al., 1978; Haslam, 1981), though it may depend on the nap taking place outside of the circadian trough (Naitoh, 1981).

Similar improvements in physiological indices of activation have been reported following naps by sleep-deprived (Haslam, 1981) and non-sleep-deprived subjects (Taub, 1977). Though we could not replicate Taub's (1977) physiological results for non-sleep-deprived habitual nappers, this may in part have been due to methodological differences between the studies, including nap length, frequency of measurement, adaptation of the subjects to the laboratory, subjects' napping expectancies, and activities intervening between the nap and measurement. Despite the lack of consensus between laboratories in the area of post-nap behavioral and physiological efficiency in habitual nappers, there is full agreement that nappers report naps help them function, and the increase in positive mood states after naps fully supports this contention.

This result alone suggests napping to be beneficial to morale and thus an effective stimulus to positive motivations necessary to resist the consequences of sleep loss during sustained operations. We propose that napping in advance of accumulated sleep debt is likely to provide the individual with greater resiliency to the effects of sleep loss, and allow him to function more effectively over a longer period of time. The

next study should seek to directly test whether or not a brief nap in advance of sleep deprivation would not positively affect an individual's response to deprivation. This would determine the efficacy of napping prophylactically. Following this, and to some extent regardless of the outcome, studies should be done to investigate the degree to which individuals can gain control over their sleep onset to determine if during slack periods of quasi-continuous work schedules they can sleep at will prior to the next sustained work period. Some of the data we collected in the current study bears directly on the issue of control of sleep onset.

3. The Control of Napping.

The survey data make it clear that napping is quite common among the adult college population, with around 55% habitually napping at least once a week, and another 29% indicating they could nap if they had the time or needed the sleep. The remaining are habitual non-nappers who either report not being able to nap (6%) or that naps produce unpleasant aftereffects causing them to avoid napping (8%). While the napping percentage is in good agreement with other surveys of this population (Lawrence, 1971; Webb, 1975; White, 1975; Kunken, 1977), this is the only data we know of exploring the reasons why individuals do or do not nap (see also Evans & Orne, 1975).

Daytime napping appears to be prevalent or possible in over three-quarters of young adults, and the bulk of the napping appears to be a

function of normal variation in sleep/wakefulness cycles resulting from busy and varied activity schedules. For example, replacement nappers make up about one-third of the population, and they nap following nights of slightly reduced nocturnal sleep due to getting up 45 minutes earlier on nap day mornings. The earlier arising time is related to activity scheduling rather than to a poor night's sleep, as evidenced by replacement nappers rating themselves as having slept well on 91% of the nights before nap days, and 88% of the nights before non-nap days. Neither percentage indicates nocturnal sleep problems. Similarly, personality tests, laboratory sleep sessions, circadian curves, and sleep diaries fully document that habitual nappers are normal, healthy, active young adults.*

There is also no data to suggest that confirmed non-nappers were unusual other than reporting naps produced unpleasant aftereffects. However, it is noteworthy that Bertelson (1979) found that habitual non-nappers had higher levels of negative affect than nappers. She attributed this to the relaxation and improved affect that comes with taking a break during the day regardless of whether it involves sleep. Nappers' naps provide such a break, while non-nappers appear not to take a break either in the form of a nap or waking bedrest. Such an explanation is not inconsistent with the bulk of the non-nappers we surveyed indicating that they did not have time to nap.

*We emphasize this again lest one reach the erroneous conclusion that habitual nappers must be suffering from excessive daytime sleepiness, and therefore are at risk for nocturnal sleep pathologies.

Though appetitive nappers make up only 12% of those surveyed, they provide a dramatic contrast to habitual non-nappers by displaying the greatest control over nap sleep onset as evidenced by their napping an average of one out of every two days (Figure 3). Further, unlike replacement nappers, appetitive nappers' nocturnal sleep did not predict their daytime napping. Their non-nap days were, however, characterized by extremely low deactivation-sleep ratings, particularly during the mid-day period when naps would typically occur (Figure 11). Curiously, this was also seen on nap DAY 3 in the laboratory, and may indicate that they expected not to nap in the alerting environment. Since they nevertheless slept on DAY 3, it is likely this lack of sleepiness on non-nap days does not cause them not to nap, rather it probably reveals an expectation that a nap is either not necessary and/or not likely, but not impossible. Replacement nappers and confirmed non-nappers may have had similar expectations about not being able to nap in the alerting environment; however, they increased the likelihood of overcoming these expectations by increasing their daytime sleep need through shortened nocturnal sleep the night before (Figure 14).

The fact that both appetitive and replacement napper groups showed a characteristic pattern of increasing sleepiness and calmness with decreasing activation between noon and 4 p.m. on nap days relative to non-nap days suggests that these pre-nap subjective changes are probably not related to sleep need in terms of shortened nocturnal sleep. Similar changes were observed in the laboratory for all subjects who slept, including

non-nappers, as the nap onset time approached, such that by nap onset activation and sleepiness ratings were significantly below the values for the onset of wake control periods. These subjective changes, together with the lower temperatures nappers had on nap days relative to control days and non-nappers, reflect a pre-nap psychophysiological preparation on the part of nappers characterized by lowered activation. The result may not be inseparable from the natural biorhythmic decline in activation in the early afternoon, and it is obviously not possible to know whether it actually causes napping. Nevertheless, non-nappers who were unable to nap in the laboratory did not show this pre-nap decline in activation, and they typically averaged the highest pre-nap oral temperature.*

Thus, an ability to prepare for a nap by lowering activation may be a central component to being able to control nap sleep onset at a variety of times and in varying environments, as appetitive nappers appear to be able to do. We suspect that the vast majority of individuals, including many habitual non-nappers, possess this capacity but do not use it often enough (i.e., nap) to make it seem voluntary. Replacement napping suggests that an impetus such as slightly shortened nocturnal sleep is necessary to permit most individuals the justification

*Taub (1977) has noted that temperature changes across naps may not be consistent with other psychophysiological indices of activation, and has therefore suggested that this raises problems for activation considered as a unitary concept. It may be that activation cannot be considered unidimensional, but it is also relevant to note that temperature may be more informative prior to naps, as a predictor of the likelihood of sleep and its consequences, than after naps.

and propensity for decreased activation that may serve to facilitate napping. However, an application of prophylactic napping to quasi-continuous performance situations would seek to enhance the individual's control over the ability to nap without an increased sleep need. Further work is needed to explore the techniques that will enhance the control of sleep onset at various times and under less than optimal circumstances.

DIRECTIONS FOR FUTURE RESEARCH

This study has provided new information on the nature, control, and consequences of napping, and has raised a number of theoretical and practical issues relevant to an understanding of sleep. Since we have summarized a massive amount of data, it may be useful to review what we have learned from the perspective of prophylactic napping and its potential application and to discuss those issues that will need to be addressed in future research concerned with developing ways to maintain effective functioning during quasi-continuous operations.

The conceptual distinction we initially made between replacement napping (only when tired) and appetitive napping (even when not tired) relates to different sleep/wakefulness patterns. Napping appears to result from a different kind of increased sleep need in each instance. While replacement napping occurs in response to nocturnal sleep need, appetitive napping may satisfy a biphasic sleep cycle where napping is the second sleep phase, providing more total sleep time and a break from prolonged wakefulness. The replacement-appetitive distinction not only permits us to document that naps are used to supplement relatively small fluctuations in the amount of nocturnal sleep, but also suggests that napping may provide the necessary sleep to permit individuals to function for prolonged periods. This raises the intriguing possibility that the benefits of napping can be "stored" in advance of sleep loss, that is, prophylactic napping.

While we share a profound interest with our scientific colleagues

in the theoretical question of whether sleep can be stored (see Moses, 1978), it should be emphasized that from a pragmatic point of view our primary aim is to apply prophylactic napping to sustained operations. Even if it were not possible to store whatever benefits are derived from sleep, an individual capable of utilizing a slack period for napping would enter into a period of continuous performance having slept far more recently than other personnel who had remained awake throughout. Thus, at the very least, the amount of wakefulness prior to prolonged sleep deprivation would have been reduced. The utilization of slack periods during quasi-continuous performance would tend to further limit the accumulation of sleep debt.

One of the major limitations on the deployment of prophylactic napping is the period of time following sleep that an individual is unable to function effectively. Our data clearly show that the immediate post-nap decrement in simple reaction time performance is related to the stage of sleep upon awakening, but the decrement in complex cognitive performance (which is of far greater importance) is related to the total time in deep (non-REM) sleep during naps. The performance decrement may persist for a considerable period of time. Research is needed to determine what if any procedures can minimize the duration of time performance is impaired following a nap. Enough is known, however, to suggest that in sleep-deprived individuals napping will result in a more profound and longer post-sleep performance decrement than seen in individuals who nap without prior sleep loss.

In considering continuous operations, the choice is not whether personnel will nap, but rather whether this will occur at optimal times under the control of the individual, before he is sleep-deprived, or whether it will occur largely involuntarily in a sleep-deprived individual whose performance is already impaired. Since it appears that the time of day selected for a nap is of crucial importance for its effectiveness in maintaining functioning (see Naitoh, 1981), prophylactic napping undertaken voluntarily by trained personnel will be far more effective and lead to considerably shorter periods of vulnerability than sleep that otherwise typically overtakes personnel at the circadian trough when they are least likely to benefit from a nap. The essential components to prophylactic napping would appear to be utilizing available sleep opportunities early on, at the appropriate times of the circadian cycle -- prior to the accumulation of sleep debt.

Our data indicate that some 55% of the young adult population nap habitually and at least another 30% have napped in the past and report that they would be capable of napping if it were necessary or desirable to do so. Since soldiers seeking to practice prophylactic napping would not be sleep-deprived, would be in a stress situation, and lack desirable sleep opportunities, even habitual nappers would probably find it difficult to achieve sleep without some specific sleep discipline training. Our work suggests that such training should be possible and relatively easy for a very large majority of the population. In addition to individuals learning the skill of controlling sleep onset, it is equally

important to consider some of the social psychological procedures that would make napping an acceptable activity for military personnel. This is true not only for enlisted personnel but probably even more important for both junior and senior officers.

The current research further supports our view that the systematic use of napping during slack periods of sustained operations -- for the purpose of facilitating continued effective functioning -- seems to be a practical way to prevent the debilitating effects of sleep loss on personnel. Future research will be directed toward a test of the value of a nap in advance of sleep loss, and to the study of factors that will enhance individuals' control over sleep onset as well as sleep offset.

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APPENDICES

- I. Survey of Subjective Sleep Patterns (Napping Questionnaire) . . . A-1
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- II. Patterns of Sleep Questionnaire Form SD: Sleep Diary++ A-12
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Survey of Subjective Sleep Patterns

Name: _____ Date: ____/____/____
 first middle last

Date of Birth: _____ Sex: _____ Class: _____

Address: _____ Phone: _____

People vary greatly in their patterns of sleep and in their preferred times for sleeping. We are interested in obtaining data on various patterns of night-time sleep and also on the frequency of ability to sleep during the day time. We would very much appreciate your cooperation in giving us information on how you sleep, when you sleep, and how deeply you sleep, by filling in this questionnaire.

Please answer each question by checking the appropriate description of the frequency of occurrence or by filling in the blanks on the questions which have them. There is room for general comments at the end of the questionnaire. Please answer every question.

1. How many hours of sleep did you have last night? _____
2. During the past year, how many hours of sleep have you regularly had? _____
3. How many hours of sleep would you like to have each night? _____
4. How many hours of sleep do you feel you need each night? _____
5. Do you sleep as deeply as you would like? Yes _____ No _____
6. When you first wake up, do you typically feel slow and lethargic? (Yes _____ No _____) or do you typically feel refreshed and ready to go? (Yes _____ No _____)
7. Did you sleep well last night? Yes _____ No _____
8. Do you usually sleep well? Yes _____ No _____
9. Could you go to sleep now if you had the time? Yes _____ No _____

10. Sometimes what people do before falling asleep influences how well they sleep. Some people count sheep, others unwind by reading a science fiction novel before turning off the light. Some people like a hot drink, but this would be considered most undesirable by others. While many of us brush our teeth before retiring, others may look under the bed.

Describe briefly those activities you typically complete before falling asleep which you feel help you to sleep well. _____

11. People describe many personal preferences about the conditions under which they sleep best (e.g., some people cannot sleep with a fan blowing on them, others feel they cannot sleep unless they are close to an open window).

List as specifically as you can three special conditions which are most likely to help you sleep well:

1. _____ 2. _____ 3. _____

List three conditions you sometimes encounter under which you have a great deal of difficulty sleeping well:

1. _____ 2. _____ 3. _____

12. Indicate the appropriate times when:	Last night		Usually	
	Hour	am/pm	Hour	am/pm
a. You felt very sleepy				
b. You went to bed				
c. You fell asleep				
d. You woke up during the night				
e. You woke up in the morning				
f. You got out of bed				

INSTRUCTIONS FOR PART II

The last question you answered read:

23. Do you take catnaps during the day?

Your answer to this question was:	Always	_____
	Usually	_____
	Sometimes	_____
	Rarely	_____
	Never	_____

Like so many other things, some people nap regularly, and others never take naps, while most people fall somewhere in between--napping on occasions depending on a variety of circumstances. We are interested in studying some of the reasons why some people nap, but others do not, and what are some of the characteristics which account for whether people nap. The next part of this questionnaire is divided into two sealed sections, one colored green, on pages 5 - 7, and one colored blue, on pages 8 - 11. You should complete only one of the two sections, depending on your answer to question 23 regarding napping.

(a) IF you answered question 23 either Rarely or Never (indicating that you rarely or never take catnaps), you should turn to the green Section II on the next page (page 5), break the seal, and complete it. Do not complete the blue section beginning on page 8, and please do not break the seal on the blue section. The information you are providing, together with what you have already provided, is extremely important because it will be possible to determine whether there are differences in the patterns of sleep of those who rarely or never nap compared to those who do nap on at least some occasions.

(b) IF you answered question 23 either Always, Usually or Sometimes, indicating that you catnap at least sometimes, you should turn to the blue Section III on page 8, break the seal, and complete it. Do not complete the green section on page 5, and please do not break the seal on the green Section II (pp. 5 - 7). By answering the following questions, we will learn a great deal more about the characteristics of napping.

In summary, on the basis of your answer to question 23 about how often you nap, determine whether you should complete Section II (green) or Section III (blue). Complete the appropriate section, breaking only its seal. DO NOT break the seal of the section you do not have to complete.

Break the seal and continue only if you answered Question 23
either "Rarely" or "Never" (indicating you tend not to take catnaps).
Otherwise, if you do catnap, turn to the blue section (page 8).

Section II

1. Listed below are several reasons why a person may rarely or never nap. Please check each reason on the five point scale: 5 indicating the reason quite definitely applies to you; 1 indicating the reason is largely irrelevant.

	Definitely Applies	Irrelevant			
	5	4	3	2	1
a. No time available					
b. Napping is an unpleasant experience					
c. I do not have any need to nap					
d. Napping interferes with my work (studying)					
e. Napping interferes with my leisure entertainment					
f. I would not be able to fall asleep					
g. I would not feel any better after napping ...					
h. I would not feel any less tired after napping					
i. If I napped, I would not be able to sleep well at night					
j. I already get enough sleep, so do not need to nap					
k. Napping produces unpleasant physical aftereffects					
l. Napping produces unpleasant mental aftereffects					
m. Resting without falling asleep is more beneficial					
n. Napping is a sign of laziness					
o. Other reasons (specify) _____					

2. Which, in order of importance, of the above reasons, are your main reasons for not napping? 1 _____ 2 _____ 3 _____
Which of the above reasons are least important? 1 _____
2 _____ 3 _____

3. Was there a period of time when you did take naps at least sometimes?
 Yes _____ No _____ When? _____

4.

- a. What time of the day do you usually feel most alert and awake?
 b. What time of the day do you usually feel most tired and sleepy?
 c. What time of the day do you feel you work most efficiently?
 d. What time of the 24 hour day would you most prefer to go to sleep?

Hr	am/pm

5. Under what ideal conditions would you be most likely to nap? _____

6. What do you think are the main differences between naps and regular sleep?

7. In what other ways do you think a person who regularly naps might differ from a person who never naps? _____

8. In our attempts to explore the characteristics of napping and nonnapping behavior, we have undoubtedly failed to mention several aspects of your own behavior and thoughts about the topic. Any other comments that you feel might be relevant would be extremely valuable to us.

Break the seal and continue only if you answered Question 23
either "Always," "Usually" or "Sometimes" (indicating you do take
catnaps on at least some occasions).

Section III

1. How often do you take naps? per month or per week

2. When did you last nap? Day _____ Time from: _____ until: _____

3. What time of the day do you prefer to nap?

4. What time of the day do you least like to nap?

5. What time of the day do you feel most tired and sleepy?

6. What time of the day do you feel most alert and awake?

7. What time of the day do you feel you work most efficiently?

Hr.	am/pm

8. How long would the ideal nap last for you?

9. What is the longest period of time you nap?

10. What is the shortest period of time you nap?

11. When napping, how long does it take to fall asleep?

12. When you do nap, how long does it typically last?

13. How long after you awaken in the morning does it take before you are ready to take a nap?

14. How long before you plan to go to bed for the night would be the minimum time you would plan not to take a nap?

Hrs.	Min.

15. Check which of the following alternatives you think you would prefer:

i. A regular (8 hours or so) continuous night's sleep

ii. Several short naps throughout the 24 hour day when you felt tired.

29. What are the conditions under which you are most likely to nap?

30. Do you sometimes feel that a nap was not very refreshing, and that perhaps you wish you had not napped? _____ If Yes, what is it about the circumstances that leads you to think so; why do you think some naps are like this? _____

31. What do you find are the main differences between regular sleep and naps? _____

32. In our attempts to explore the nature of napping, we have undoubtedly failed to mention several aspects of your own napping behavior. Any other comments that are relevant to naps that you take would be extremely valuable for us. _____

APPENDIX II

UEP:2-NONS-78/79

Patterns of Sleep Questionnaire

Form SD: Sleep Diary ++

Name: _____ Day: _____
First Middle Last

Date: ____/____/____ Time of Day: ____ hour ____ a.m. or p.m.?

Instructions:

People vary greatly in their patterns of sleep and in their preferred times for sleeping. We are interested in obtaining data on various patterns of nighttime sleep and also on the frequency of the ability to sleep during the daytime. You have previously completed a questionnaire regarding your general sleep patterns and we would very much appreciate your cooperation in giving us further information regarding how you slept last night by filling in this questionnaire.

For consistency of the data it would be helpful if you could complete the diary as soon after getting up in the morning as possible. Most people find that keeping the sleep diary on a small table or chair close to the bed aids in reminding them to answer the sleep diary questions upon arising for the day.

Please answer each question by checking the appropriate description of the frequency of occurrence or by filling in the blanks on the questions which have them. There is room for general comments near the end of the questionnaire. Please answer every question.

1. How sleepy are you now?

very sleepy _____ drowsy _____ normally tired for this time of day _____
in a normal wake state _____ wide awake, too awake to sleep _____

2. Did you sleep well last night? _____

3. How deeply did you sleep last night?

very lightly; as lightly as I have ever slept. 1 2 3 4 5 6 7 8 9 10 very deeply; as deeply as I have ever slept.

4. What time did you wake up this morning? _____
hour a.m. or p.m.?
5. How did you awaken this morning?
☐ spontaneously ☐ alarm clock ☐ friend ☐ telephone ☐ other _____
specify
6. What time did you get up this morning? _____
hour a.m. or p.m.?
7. What time did you get into bed last night? _____
hour a.m. or p.m.?
8. When you got into bed last night, did you read or watch television, etc., before "shutting off the light" and attempting to go to sleep? ☐ Yes ☐ No
9. After you "shut off the light," what time did you start to try to go to sleep? _____
hour a.m. or p.m.?
10. Approximately what time did you go to sleep? _____
hour a.m. or p.m.?
11. About how long did it take you to fall asleep last night? _____
hours minutes
- 12a. Did you wake up during the night? ☐ Yes ☐ No
- b. If yes, how many times? _____
- c. Roughly how long each time? _____
hours minutes hours minutes
- 13a. Did you get up during the night? ☐ Yes ☐ No
- b. If yes, how many times? _____
- c. Approximately how long each time? _____
hours minutes hours minutes
14. How many hours did you sleep last night? _____
hours minutes
- 15a. Did you dream last night? ☐ Yes ☐ No
- b. If so, do you recall the general content of any of the dreams?
☐ Yes ☐ No
16. Have you taken any medications in the past 24 hours (e.g., No-Doz, Darvon, aspirin, cold pills, penicillin, codeine, hayfever pills, etc.)?

Please list: _____

17. How many hours did you spend outdoors yesterday? _____
hours minutes

18a. Did you perform any regular physical exercise for 30 minutes or more yesterday? ☐ Yes ☐ No

b. If yes, please describe briefly: _____

Time of day: from _____ to _____
hour a.m. or p.m.? hour a.m. or p.m.?

19a. Did you perform any special, or any more than usual, physical exercise yesterday -- even if only for a short time? ☐ Yes ☐ No

b. If yes, please describe briefly: _____

Time of day: from _____ to _____
hour a.m. or p.m.? hour a.m. or p.m.?

20a. Did you concentrate especially hard, or more than usual, on any special task yesterday? ☐ Yes ☐ No

b. If yes, please describe the task briefly: _____

Time of day: from _____ to _____
hour a.m. or p.m.? hour a.m. or p.m.?

21a. When yesterday did you feel most tired? _____
hour a.m. or p.m.?

b. How long did the tiredness last? _____
hours minutes

c. Taking yesterday morning, afternoon and evening separately, please indicate at approximately what time you felt tiredest, and how long the tiredness lasted.

Morning Afternoon Evening

from ____:____ to ____:____ from ____:____ to ____:____ from ____:____ to ____:____

not tired at all ☐ not tired at all ☐ not tired at all ☐

22a. At any time yesterday did you have the impression that you were "fighting off" sleep or that your eyes kept closing "against your will"? ☐ Yes ☐ No

b. If yes, approximately when? hour a.m. or p.m.?

23a. At any time yesterday, were you ever so tired that you had difficulty concentrating on a task which you were trying to accomplish? ☐ Yes ☐ No

b. If yes, from to
a.m. or p.m.?

Please describe briefly the task: _____

-4-

UEP:2-NONS-78/79

24a. Did you take any naps yesterday?

☐ Yes☐ No

b. If yes, how many? _____

c. How long? from _____:_____ a.m. or p.m.? to _____:_____ a.m. or p.m.?

from _____:_____ a.m. or p.m.? to _____:_____ a.m. or p.m.?

d. How did you feel when you got up? _____

e. Was the nap a good one? ☐ Yes ☐ Nof. Did you feel refreshed after the nap? ☐ Yes ☐ No

g. How did you awaken from the nap yesterday?

☐ spontaneously ☐ alarm clock ☐ friend ☐ telephone ☐ other _____ specifyh. I napped yesterday . . . ☐ lying down ☐ sitting up

25. During what time period yesterday did you feel the most awake?

from _____:_____ to _____:_____ a.m. or p.m.?

26. Approximately how many hours yesterday were you

in classes _____ studying _____ at work _____
hours # hours # hoursother _____ tasks or activities requiring concentration _____
please specify briefly # hours

27a. What was the most important task you accomplished yesterday? _____

b. Between what times was this task accomplished?

from _____:_____ to _____:_____ a.m. or p.m.? a.m. or p.m.?

28. ~~Additional comments~~ regarding your sleep last night or about your wakefulness or drowsiness yesterday: _____

29. How many cups of coffee or tea did you have yesterday? _____

30. How many cups of coffee or tea have you had during the past 3 hours? _____

31. How sleepy are you right now?

wide awake;
absolutely no
desire to
sleep or rest

1 2 3 4 5 6 7 8 9 10

the need for
sleep is over-
whelming; sleep
is unavoidable32. Could you go to sleep now if you had the time? ☐ Yes ☐ No

APPENDIX III

Preferences for Background Sounds or Silence

Name: _____ Date: _____
first middle last

Please check the appropriate box that applies to you for each question.

	ALWAYS	USUALLY	SOMETIMES	RARELY	NEVER
1. Do you study with the radio or a record player on?					
2. <u>Can</u> you study with the radio or a record player on?					
3. Do you prefer to study with only one light on in the room and all the others off?					
4. If you have something important to concentrate on, do you prefer a completely quiet room in which to work?					
5. <u>Can</u> you concentrate on something important with a conversation in the background?					
6. Do you prefer to go to sleep with music playing at a low level?					
7. <u>Can</u> you go to sleep with music playing at a low level?					
8. When you decide to go to sleep, do you insist on quiet surroundings?					
9. If familiar sounds occur during your sleep time--such as a regular elevated train going by your window or other students talking outside your dormitory or apartment--are you able to sleep through these occurrences?					

	ALWAYS	USUALLY	SOMETIMES	RARELY	NEVER
10. Do you study with the television on?					
11. <u>Can</u> you read a textbook while the television is on?					
12. <u>Can</u> you read a novel while the television is on?					
13. In order to go to sleep or nap, do you prefer to put the television or radio on before doing so?					
14. <u>Can</u> you go to sleep or take a nap in a movie (or play or concert) which perhaps does not interest you (but where you can't yet leave)?					
15. Do you find it easier to study with someone else around?					
16. If you have work to do, do you work better with sounds in the background?					

17. For what kinds of work do you prefer complete quiet? _____

18. For what kinds of work do you prefer some background sounds? _____

19. What types of background sounds, if any, are for you conducive to working? _____

20. Comments with regard to your own feelings about background sounds during sleep:

21. Comments with regard to your own feelings about background sounds during times you are working:

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SLEEP NAPPING FATIGUE PERFORMANCE SUSTAINED OPERATIONS	EEG CIRCADIAN RHYTHMS ACTIVATION MOOD CONTROL OF SLEEP	PROPHYLACTIC NAPPING ENVIRONMENTAL EFFECTS PSYCHOPHYSIOLOGY REPLACEMENT NAPPERS APPETITIVE NAPPERS
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Quasi-continuous work schedules require individuals to function for pro- longed periods with few extensive sleep opportunities. Consequently, sleep loss may jeopardize effective functioning. The aim of our research has been to evalu- ate the potential of napping to facilitate functioning in such situations. Our studies have focused on identifying basic individual differences in napping be- havior, and determining the implications of these differences for the ability to nap, the nature of naps, the purpose served by naps, and the consequences of		

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napping in both sleep-conductive and non-conductive (alerting) environments. These issues are highly relevant to the implementation of prophylactic napping during sustained operations. We present an extensive study involving both laboratory and field data on the sleep/wakefulness patterns, napping behavior, psychophysiology, performance, subjective activation, and circadian variation in two types of habitual nappers and a group of habitual non-nappers. Replacement nappers nap to compensate for shortened nocturnal sleep the night before, and are the most common type of nappers; appetitive nappers' naps are not tied to reduced nocturnal sleep, but rather may be part of a natural biphasic sleep cycle. Appetitive nappers exhibit a greater control over napping than replacement nappers. Confirmed non-nappers avoid napping because it produces unpleasant consequences for them, the basis of which might be the intrusion of a consolidated nocturnal sleep pattern into their nap. Naps profoundly improve positive mood states in nappers, but they also yield immediate post-nap performance decrements--related to aspects of sleep infrastructure--that are relatively quickly dissipated. Alerting environments and intense waking stimuli do little to lessen the decrements. An alerting nap environment increases the proportion of light sleep during a nap while reciprocally decreasing deep sleep, but only marginally diminishes the subjective benefits of a nap for nappers. Nappers preparing to nap show lowered activation levels. This may reflect an increased sleepiness due to sleep need, as seen in replacement nappers, or be indicative of control over daytime sleep, as seen in appetitive nappers. This preparatory response--which appears to predict whether sleep will occur--has implications for training soldiers to use available slack times for napping during quasi-continuous operations. Our findings are reviewed in the context of relevant literature on napping and fragmented sleep and interpreted in terms of contemporary theories of sleep function. We propose that the next study involve a specific test of the efficacy of prophylactic napping to minimize the accumulation of sleep debt and its accompanying performance deficit. Finally, future investigations should focus on factors that may enhance the control of sleep onset (without sleep debt), and the attenuation of the negative effects of sleep offset.

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